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For: Teachers and Technicians in Technical Subjects and the Sciences

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Festive season closure - please note that the Centre will close for the holiday on Friday 20th December and re-open for business on Monday 6th January 1997.

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NEWS AND COMMENT

New SSERC address

Once more we have to apologise to readers for the lateness of an issue. If last year was an *annus horribilis* for the Royals then this present one has been fairly horrible for Scottish Local Government in general and education in particular. Like everyone else involved in the shake-up, we have been somewhat pre-occupied just ensuring our survival. Perhaps by now we're just addicted to stress but, partly as a matter of economy as well as for other reasons, (sheer masochism?) we have moved, again! Our new address details are given in the usual list on the rear, inside cover. In case any reader misses that entry, we repeat it here :

SSERC, St. Mary's Building,
23 Holyrood Road,
Edinburgh; EH8 8AE
Telephone : 0131 558 8180
Facsimile : 0131 558 8191

Afficianados of Albion's capital cityscape should recognise the above address as the Moray House Institute block nearest to the Holyrood Tavern. Such proximity is a mere coincidence. In any event there are, in our view, superior howffs in Canongate and up the Cowgate. Nor need the teetotallers amongst you feel neglected with Clarinda's Original Tea Room only a scone's throw away on the Royal Mile. Our only worry is that we are now such a superior educational tourist attraction we will be swamped by the ubiquitous and footloose antipodean teaching profession, at least half of which at any one time is apparently on a sabbatical ("A what?" I hear you say).

Please note, that like a number of other national agencies who are now our neighbours, whilst we may be *in* it - in more ways than one - we are not in any sense *of* the Institute.

Membership

This sub-section seems possibly more than a tad superfluous. It is nonetheless necessary for the removal of doubt as to who is currently entitled to access the SSERC service. The majority of the new unitary councils (twenty six out of thirty two) are contributing to the Centre. A significant number are also in formal, corporate membership of the company which controls its affairs. By definition, if you came by this present issue through the normal distribution channels then your new council (independent school, FE college etc) is a subscriber. Please do not however pass on SSERC publications, or any material information therein, to third parties without copyright clearance from us. It simply isn't fair on those who are supporting the Centre financially for other authorities or institutions to be so subsidised.

National chemistry conference

Advance notice has recently been given of an inaugural National Chemistry Conference to be held at St. Andrews University on the 22nd of May 1997[1]. The more cuddly amongst the chemists are obviously feeling somewhat out in the cold now that the IoB has joined the IoP in holding an annual educational bunfight. The chemistry education do is supported by The Royal Society of Chemistry and the University's School of Chemistry. The conference is entitled :

"Issues in Chemistry Education"

There will an opportunity for participants to learn about some recent advances in a number of areas of chemistry - particularly those related to the new Higher Still courses. There will also be an update on that particular curricular development. Finally, and possibly most importantly, there will be the chance to meet chemistry teachers from all over Scotland and to discuss issues of common interest (back to favourite howffs again!). For further information contact either Nigel Botting at the University or, that cuddliest chemist of them all, Wilson Flood of Dumfries and Galloway Education Department (see Address List, inside rear cover).

ASE Scotland meeting

Yet another set of dates for the diary - the Annual Meeting of ASE Scotland will take place over the weekend of 7th to 9th March 1997. It will be held in the Edinburgh Conference Centre at Heriot Watt University, Riccarton. Last year's meeting in Dundee was by all accounts a well attended and highly successful affair. Avoiding the Easter holiday period seems to have been a smart move. We certainly hope the 1997 event will build on that success. We shall carry further detail on how to book as a participant and with whom in our Winter edition. Suppliers and others wishing to exhibit at the meeting should contact Pauline Anderson at the address given on the inside rear cover of this present issue.

TEP moves on

The Technology Enhancement Programme, funded by the Gatsby Trust and managed by The Engineering Council, has moved to a new Central London office. There it will be joined by a number of other Gatsby-funded projects in the fields of science, maths, IT and engineering education (again see Address List - last page of this issue).

[1] How kind! How did they know that's your Editor's birthday? I will accept the cake but only if someone other than a chemist bakes it.

Smaller still - curricular paradoxes?

It's been known for me to be chided gently by my colleagues for an apparent obsession with a top-down approach to problematic, professional matters. I'll admit to a weakness in preferring to see wood rather than arboreta. I like themes, am hooked on logic and an addict of the so-called 'Big Ideas'. It is that last named which I crave particularly at the moment. They seem conspicuous by their absence in some of the current curricular changes in science and technology education.

In a feature article, "Clyde-built", Bulletin 182, Jim Jamieson discussed the problem we face at the moment in motivating some youngsters (and the more general public) and in stimulating or sustaining their interest in science, technology or engineering. He suggested that, in the past, many products of engineering or technology held us in thrall because of their huge scale. He went on to speculate whether now the opposite might not be a possibility, that modern marvels are to be found in the very small. The example offered in that article was of an electrical motor with a rotor only one hundred micrometres across, rotating on a spindle ten micrometres wide. This is the world of nanotechnology. The more one contemplates this idea, the more it appeals to us thematic types. It may well offer at least one useful unifying thread stretching across all three of the major sciences and deep into technological territory.

For example, a technical article in this current issue describes the operation of MOSFETs. The aim however in studying such microelectronic devices is not to suggest curricular modernisation for the sake of mere modernity. In fact their operation is based on a useful number of fairly elementary physics principles. The use of microelectronic devices as vehicles for learning and teaching is thus intended partly to provide a means both to update the context in which such ideas are taught and then to test the learner's understanding of them. Similar approaches are entirely possible in learning and teaching in biology and chemistry. A number of articles on biochemical engineering at the molecular level have appeared here recently and in several other science education journals. There is another in this issue. Yet, the biological principles behind the extraction of nuclear acids from cells by disrupting membranes, and their subsequent analysis using enzymes, should be understandable to anyone taking a first or second examination course in biology or chemistry. It is perhaps in the latter subject where the search for modern contexts would seem most urgent. Again nanotechnologies may provide at least part of the answer.

We first carried an account of the, then new, form of carbon, C_{60} or buckminsterfullerene, in Bulletin 174. By now, most science teachers will know something of this molecule. The recent joint award of a Nobel prize to a British scientist has raised the public profile of the whole business of so-called *designer molecules*. Whilst C_{60} has already found application, there are even more exciting prospects on the horizon - a fourth generation of polymers known as dendrimers.

Donald Tomalia, at one time a researcher at Dow Chemicals but now with Dendritech, which he founded, is widely credited as one of the key pioneers in this field, which has taken the design of plastics into the three dimensional. Now there are reckoned to be at least 120 research groups worldwide beavering away on their own dendrimer designs for different purposes. Each such designer molecule may have its own type of application. These range from highly targeted therapeutic drug delivery to the storage of information by electron capture. Each may take many months to synthesise even in relatively small quantity. On the other hand they are potentially extremely high value products. In a recent *Scotsman* article Donald Tomalia explained how he parted company with Dow, then a mostly large scale, traditional, chemical conglomerate. He was quoted on how he left that company to found Dendritech : "*Dow didn't want to develop a product that couldn't be sold in truckloads*". He went on to highlight the irony that a mere kilogram of a useful dendrimer may have revenue earning potential of 50 million US$.

So, just one really big idea[1] to be pursued in modern science and technology education is - paradoxically - the very small.

Suitable topics include microbiology, microelectronics and other forms of engineering on the molecular scale. Teachers of science specialisms may have to prove yet more willing to share their territories. This need not be too problematic if we stick to the idea that the aim of a school biology, chemistry or physics course is to provide a sound grounding in that particular subject. What we are discussing here is the use of more contemporary, possibly multidisciplinary, contexts in which to set learning and teaching activities.

There is a second paradox. This arises from the nature of current curricular reshaping. It would seem that some aspects of Higher Still might actually make it more difficult rather than less to properly pursue big ideas in science and technology, such as the very small.

Which brings us back to those MOSFETs. These devices offer splendid opportunities to update some contextual aspects of school and college physics courses. They provide a contemporary means by which to teach some fundamental physics. One would have thought that the modular structure of the Higher Still proposals would provide just the flexibility needed to begin such updating. Ironically, it seems that a modular approach with a mix of internally assessed, stand alone, chunks taken with an holistic, external, course assessment may instead create difficulties for anyone seeking to use thematic approaches to update curricula. Should anyone else have spotted and solved this problem then answers please in an i.c., codon or - if you have the time - a dendrimer, to the Higher Still Unit and the new Scottish Qualifications Authority.

[1]There are several others to do with matters such as environmental issues and sustainable development but space precludes etc . . .

Prosecution under IRR(85)

It has come to our attention from the literature [1] that a University has been successfully prosecuted under regulations 11 and 19 of the Ionising Radiations Regulations 1985 (IRR85). The case involved student usage of a 2.2 mBq, Ra-226 calibration source which subsequently went missing. The laboratory was searched but the source was not recovered. It was thought either to have been disposed of with routine laboratory waste or had been taken away by the student. The Local Rules in force at the time made no reference to proper procedures for using and returning such a calibration source and accounting procedures were poor.

This incident illustrates the importance of having comprehensive coverage within the Local Rules of all relevant applications of sources and above all of adequate accounting procedures and records. Readers are reminded that such matters are dealt with in the appropriate SSERC publication [2]. In particular the notes stipulate (Para. 81) the use of a log book to record each usage of any source including the date of such usage, the sources used and the name of the user withdrawing and returning them from and to the store.

References

1. *Feedback From Inspectors*, The Radiation Protection Adviser, Issue 7, May 1995, HSE.
2. *Protection against ionising radiation in science teaching :* Explanatory notes on local rules for teaching establishments (SED Category C only), SSERC, 1987.

Health and safety bibliography

At the request of a number of the new unitary authorities SSERC has recently produced a bibliography of health and safety regulations and guidance for the education sector. The document sets out to list all legislation having an effect on health and safety relevant to schools in Scotland. At the request of client Councils the listing goes well beyond SSERC's more traditional science and technology education remits, taking in all types of work and workplaces within schools. A number of currently contentious areas such as outdoor activities, school transport or trips and school security, are also referenced.

The list is set out in four columns. The first specifies the broad health and safety category, "Outdoor Education", "Hazardous Substances" etc. The primary legislation (Act of Parliament or other Statutory Instrument) and any dependent Regulations or other secondary legislation are cited in the next column. Guidance, codes of conduct and relevant standards appear in the next two columns. These are divided into those of general application, in which case they appear in column three and those which have specific application to schools or like establishments, in which case they are in the fourth and final column.

Copies of the listings were circulated earlier in the year to every Council in membership of SSERC. Single copies were also sent to subscribing independent schools and colleges. Further copies are however available to individuals within member authorities or establishments on request from the Centre. They are priced at £6 per copy including post and packing.

Health and safety training

Before the twin upheavals of re-organisation and our recent flit, we took the chance to update our staff development brochure for general health and safety related training and management courses. We still have to finish our other more technical listings on topics such as inspection and testing etc, but copies of the more general programme are already available on request. This covers courses in health and safety management for senior staff in schools as well as for principal teachers of science or technology. There are also ASE affiliated courses for primary and secondary staff concerned with Environmental Studies 5-14 and for science technicians at secondary level.

One new venture is a specialised course for staff who might have to administer immediate remedial measures in the absence of an officially qualified and recognised first-aider. This course will be jointly tutored by SSERC staff with expertise in chemical and other toxicological matters and an HSE accredited first-aid trainer.

Should you wish to obtain a copy of the staff development brochure, or if your authority, school, neighbourhood or cluster group is interested in staging any of these courses, then please contact the Executive Director of the Centre.

Scottish edition reprinted

The Scottish edition of the ASE publication *Be Safe!* has been reprinted and is now available from either ASE Booksales or from SSERC. This user friendly health and safety booklet covers aspects of safety in science and technology in the 5-14 Environmental Studies curriculum.

SSERC has bought-in the bulk of the reprint stock and is prepared to absorb some of its distribution costs. We are able to offer copies at £4-00 (saving £0-95 on the usual non-ASE member's price) to local authority schools or subscribing independents in Scotland. Copies may also be provided as an integral part of any SSERC staff training based on the publication. It also may be possible to offer further small discounts to members where a bulk order can be delivered to a single customer. Enquiries to the Executive Director, SSERC, please.

Living materials : revised code

One of the joint, dying acts of the science and safety arms of Strathclyde Regional Council's education service was the publication of a revised code of practice on the use of materials of living origin in schools [1]. The code is similar in style to the widely adopted earlier documents on microbiological safety. As with that microbiology code, the Working Group had a majority of educational practitioners. The code thus provides pithy advice and direction on acceptable practices and procedures for schools. There are eight sections, some appendices on practical procedures and a bibliography. Nevertheless the whole document is of only twenty or so pages and easily read in a single, short session. The one page Introduction sets out the overall educational philosophy and rationale of the document. The other main sections deal with :

- *pupils as subjects of experiment or investigation;*
- *keeping animals in schools;*
- *surveying and collecting living materials from the environment for investigation;*
- *use of animal materials for dissection or experimentation;*
- *use of plant material;*
- *DNA technology and*
- *microbiology.*

Just as the Introduction provides a rationale for the code as a whole, each section begins with its own short set of statements giving clear and positive guidance on the aims and limits of such educational usage.

The Appendices may be of particular interest to many Scottish teachers. The first section of the body of the code proscribes the taking or use of human blood samples but does allow the use of both cheek cell samples and of saliva so long as recommended procedures are followed. Two of the appendices contain detailed descriptions of such procedures. Other appendices provide useful material relevant to the care of animals, lists of recommended organisms and guidance on the safe and sensitive use of Longworth traps for small mammals.

SSERC staff served as occasional consultants to the Working Group, but that's not the reason behind this rather favourable review. The teachers, University staff, and not least Jim Stafford of Ayr Division, who chaired the meetings, deserve credit for producing such a well balanced code which is sympathetic and sensitive to the needs of learners and teachers as well as to the other organisms which both may study. As with the Microbiology Code, this document deserves a place in the essential reference section of any school science department's library.

Reference

1. *Materials of Living Origin in Schools : A Code of Practice*, Strathclyde Regional Council Department of Education, 1996.
Copies of the code were distributed to members of the Scottish Science Advisory Group just prior to the demise of the old Councils. Strathclyde Region kindly waived copyright so long as the document is copied and distributed in its entirety and that no profit accrues.

Seeing red : new extinguisher colours

There is a new Standard on fire extinguisher colours. British Standard BS5423 is now a BS EN Standard which meets the requirements of European Norme EN 3 [1]. The result is that all new fire extinguishers, regardless of type, will be red. Gone will be the familiar, all-over, colour coding of black, blue, green or cream for CO_2, dry powder, vaporising liquid, or foam. Whereas before red was reserved solely for water filled types, in future the overall ground colour of every type will be red.

Manufacturers will be allowed to put on a small patch of the more familiar, older colour on the new red cylinders, provided that it is not larger than 5% of the surface area. The other good news is that you do not need immediately to buy replacement cylinders of the new colour. You have until the end of their useful working lives before having to replace any hitherto conventionally colour-coded cylinders.

Eye protector markings

Until now BS 2092 (1987) and BS 7028 (1988) have been the twin definitive guides to eye protection for both industrial and other users. BS 2092 dealt with the more technical aspects of specifying, testing and appropriate marking of eye protection and BS 7028 was a more general guide to selection, use and maintenance.

Whilst still in use until earlier this year, BS 2092 has been in the process of gradual replacement by a series of BS EN standards. BS EN 167 and 168 had already been adopted when the BSI 1996-97 catalogue was first issued. Those two European Standards deal with the optical and non-optical tests previously covered in BS 2092 although there are some differences of detail.

BS EN 166 came into effect as from 15th of April this year. This third British/European Standard completes the set as 'twere and BS 2092 is thus no more. EN 166 gives specifications and lays down appropriate markings for various types of protector. It is based not on BS 2092 but derives from the international standard - ISO 4849. You probably guessed it - that means the marking system it uses is different from that familiar from BS 2092. A more complex system using symbols and numbers has instead been adopted which covers a very wide range of specifications and properties.

The good news is that existing protectors with previously approved markings may continue in use until the end of their useful lives. You therefore need not yet worry over equivalence with BS EN 166 specifications and markings unless you are currently in the market for eye protectors. Then, strictly, the old system is irrelevant. What matters is that you match the envisaged usage with the new marking system.

For impact resistance look for "EN 166 : F" (low energy impact), or "EN 166 : B" (medium energy impact) on frame and lens. For resistance to liquid splash look for the "EN 166" mark and a "3" on the frame.

Pressure systems : autoclaves etc.

When the snappily entitled *Safety of Pressure Systems and Transportable Gas Containers Regulations 1989* were first promulgated our sister organisation, CLEAPSS School Science Service, kindly allowed to us adapt and issue to Scottish EAs a simple inspection and testing scheme for school autoclaves (including pressure cookers) and steam engines. We added our own, similar scheme to cater for the relatively small compressors used for teaching about pneumatics in courses such as Technological Studies.

The relevant specialist education section of HSE had sight of all that material and, at the time, did not demur in any significant way. As a result we then ran short training courses, often for central support staff as well as for school based technicians. In several authorities those staff carried out the routine inspection of such simple pressure vessels and things went along quite happily. We then began to get reports of outside agencies or third parties objecting to these arrangements often on matters of minor detail. An updated view was sought from both technical and educational specialists within HSE. Meetings were held in an attempt to sort out such problems. Our sister organisation took the lead in these matters, with the support of ASE, SSERC and others. School Science Service staff produced a series of new draft schemes for the inspection of such simple pressure systems as model steam engines and portable autoclaves.

The upshot of all of the drawn-out, highly complex discussions can only be described from the schools' point of view as an unsatisfactory compromise. Complications arose partly because of the opted-out or grant-maintained status of a significant number of schools south of the Border. We will spare you the detail, but it is material to the problem that the Pressure Systems etc Regulations make much of the distinction between the owner and the user of a pressure system. Much hinges also on that old chestnut - the definition of a competent person. So, for in place of two pieces of single-sided A4 paper providing both guidance and a tabulated inspection scheme for steam engines, autoclaves and pressure cookers, the School Science Service are currently trialling a series of small booklets of interim advice. The series provides advice and guidance for EAs etc as possible owners of equipment, to heads of department who may be judged responsible for selecting a suitable inspection scheme and to technical support staff or others who may have to carry out inspections or resist the excesses of external inspectors.

We are aware that the CLEAPSS, Science Service, like ourselves, remains less than happy with all of that complexity. Nonetheless, given the circumstances, they have done an excellent job of disentangling these matters. Copies of the final versions of this series of guides will be made available on loan to members and associates of SSERC. Please address any enquiry to the Executive Director of this Centre.

Possible revision : RPA requirement

There has been a supposed need for councils and others having overall charge of educational establishments, to appoint a radiation protection adviser (RPA). This apparent need arises from regulation 10 of the Ionising Radiations Regulations 1985 (see also page 3 of this issue). The duties of such an RPA are different from those of a radiation protection supervisor (RPS), one of which must be appointed in each establishment holding relevant sources. The supervisory management post of RPS remains a statutory requirement for schools and FE colleges. The additional appointment of an overall RPA was originally advised by the relevant enforcement agencies when the 1985 regulations came into force. The appointee in most local authorities was a Science Adviser.

More recently, HSE has advised that - because of the limited activity of the sources kept in schools - there is in fact no strict requirement under regulation 10 of IRR for the appointment by the employer of an RPA, although they would have no objection to such appointments made under regulation 10 (2). The need for an RPS in each establishment however, remains.

SSERC has argued for a new approach to this problem. This is not solely because of the changed interpretation of the Regulations. A number of other factors such as pressure from the EU, as well as from UK radiological protection specialists, to professionalize the role of RPA could well place educational employers and some of their employees in difficult positions. Following helpful discussion with HSE specialists, we have suggested that in place of an RPA, appointed under the IRR(85) regulation 10, educational employers instead appoint a suitably competent person under regulation 6 of the Management Regulations 1992. This person whilst not appointed under regulation 10(1) of IRR would none-theless have an advisory role as well as general oversight of an educational employer's arrangements for radio-logical protection. The snag with this suggestion is that it contravenes the advice given in paragraph 6.3 of SOEID Circular 1166, the current official advice on this subject. Paragraph 6.3 would thus require a simple amendment. The Department has been approached on this matter and we are hopeful of a satisfactory outcome. In the interim our advice, to any new Council contemplating the appointment of an educational RPA, is - hang fire!

Safer substitutes

Your attention is drawn to two other Safety Notes in the this issue which suggest two lower risk substitutes for more traditional materials and procedures. The first of these (p.22) describes the preparation and use of Sandell's reagent as a substitute for Fehling's solutions. The second suggests uses for ceramic tile material in place of ceramic paper tape as a support when heating metals or their oxides (p.23).

TECHNICAL ARTICLE

DNA from bacterial cells

A rapid extraction method is described which demonstrates the presence of deoxyribose nucleic acid in bacterial cells. The procedure also provides a simple means of distinguishing Gram-positive from Gram-negative bacteria and has potential for detecting contamination of certain types of stock culture.

The protocol to be described was brought to our attention by Dr Robert Millar. He had used it in a former professional microbiological life as a test to distinguish Gram negative and Gram positive organisms. As part of his work as a student on the postgraduate certificate course at St Andrew's College of Education, Bearsden, he has now applied it to good educational effect. It is based on a procedure described by Gregsen [1]. We have trialled the techniques and found them to be just as straightforward as Dr Millar had suggested. More elaborate methods for the extraction of DNA, from plant cells, have been reviewed in previous issues [2]. These however are mainly intended to produce extracts which may be separated by electrophoretic techniques. In schools this work tends to be restricted to pupils studying at Higher Grade or above. The method described here affords the chance for younger pupils to see nucleic acids being released from cells. It is potentially of educational value alongside those plant DNA extract techniques.

Background and theory

Techniques for extracting DNA from plant cells can be surprisingly basic. If all you want to demonstrate is the presence of DNA, getting it out of plant cells may involve nothing more elaborate than common salt and washing up liquid [3]. That type of extraction relies on the disruption of cellular and nuclear membranes, with detergent as the prime agent. The complication tends to arise when that DNA is wanted in a somewhat purer form for electrophoretic analysis. More of the biochemical trappings - purer detergent, buffers and centrifuges etc - then are needed (see reference [2]).

The different, bacterial, method described here complements work at the cheap and cheerful end of the plant DNA market. It relies on the fact that Gram-negative bacteria are lysed rapidly by relatively dilute potassium hydroxide releasing DNA, which may be picked up with an implement and observed as a viscous thread. Gram positive organisms resist lysis when so treated [1]. The technique is thus also a test differentiating Gram negative from Gram positive organisms (interested non-specialist readers - see the Text Box for a short explanation). Because some students find a reliable Gram's staining technique difficult to acquire, this is an interesting alternative. In some circumstances it also may prove useful in the detection of contamination of a Gram positive culture by a Gram negative organism and vice versa. Teachers and technicians should however remember the limitation that many bacteria are Gram variable. Some cultures are, rather like many of us, positive when young but become negative as they age.

Organisms

Escherischia coli strain NCTC 10537 (also known as *E. coli* strain B, phage host for T phages, T1-T7) is suggested for use as the Gram negative bacterial source with *Micrococcus luteus* (also known as *Sarcina lutea*) as a Gram positive control. On nutrient agar *M. luteus* produces distinctive, bright sulphur yellow colonies. Those of *E. coli* are usually creamy or off-white. The two are thus easily distinguished. Both of these organisms are listed in the HMI Guide [5] and in the Strathclyde Code [6] adopted or adapted by most Scottish EAs. *E. coli* strain NCTC 10538 (also referred to as the *E. coli* K12 strain) is an acceptable alternative for use as a Gram negative organism. Note that our own trials used only the 10537 strain. We cannot guarantee replication of our results with other Gram negative organisms. Use of these *E. coli* strains is usually reserved for Level 3 (post-16) work, but with some additional precautions (control measures in COSHH-speak) for this demonstration its use could extend down into Level 2. See the section on Risk Assessment below for more detail.

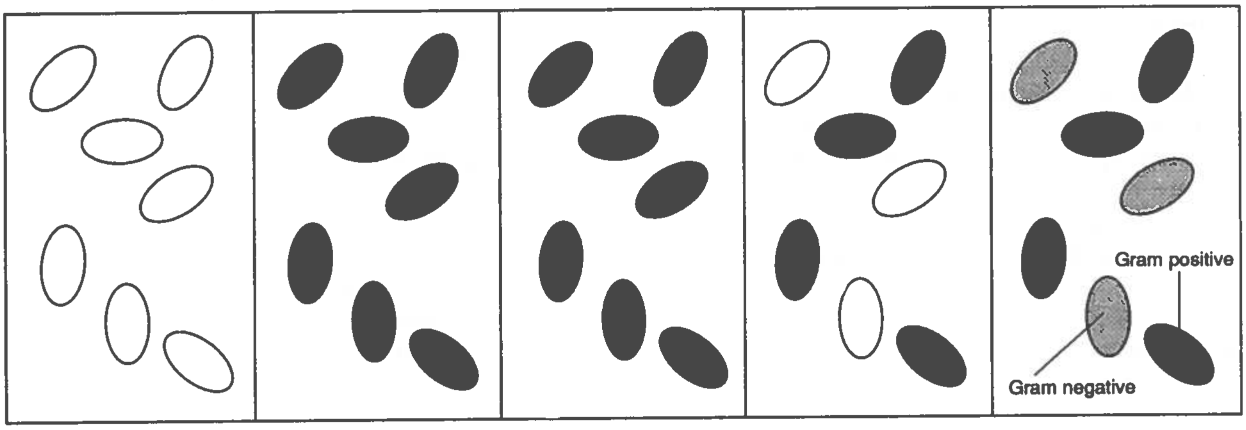
Method

Figure 2 [(a) - (d)], opposite, illustrates the sequence. Standard streaking techniques are used to produce some single colonies on nutrient agar slopes or plates. When these are at an appropriate stage :

- Place one drop of 3% w:v potassium hydroxide in the well of a clean cavity slide.
- With a flamed, metal wire inoculating loop and using standard aseptic technique, pick off a single colony (two if individual colonies are still small) and transfer into the alkaline liquid stirring to create a suspension.
- After 10 to 15 seconds begin to raise the loop from the drop and look carefully for the formation of a shortish thread, typically 20 to 30 mm, of viscous material following the loop up from the surface (rather like a micro version of the chemists' nylon rope trick).
- If at first no thread is seen, wait for a further short interval and try again.

TEXT BOX - GRAM'S STAIN

For the non-specialist reader the terms Gram negative and Gram positive require brief explanation. The distinction is based on a staining technique, perhaps the most widely used such trick in bacteriology, one with a history going back to 1884 when it was first described by a Danish worker called (no prizes sur- or otherwise) : Christian Gram [4]. Despite that history, the technique is still not completely understood. Nevertheless its results provide a useful distinguishing feature for the preliminary steps in classifying and identifying bacteria. The staining process involves several steps, two stains (one a basic stain and the other a counterstain), a mordant and a decolouriser. The end result of all this muck and magic is that certain types of bacteria end up stained red (Gram-negative) and others are violet (Gram-positive). The basic process is illustrated in Figure 1 (but note that another result of history are the many detailed variants on this technique).



(a) before staining all bacteria are colourless

(b) after basic stain *(crystal violet)* all bacteria are stained violet

(c) after mordant *(Lugol's iodine)* stain is fixed more firmly into the cell

(d) after decolouriser *(acetone-alcohol)* some bacteria are colourless (Gram negative) while others are still violet (Gram positive)

(e) after counterstain *(safranin)* colourless bacteria (Gram negative) have taken up stain and appear red; Gram positive bacteria remain violet

Figure 1 Summary of Gram's staining procedure (After Humphries. [4])

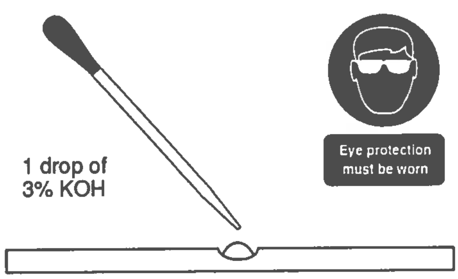


Fig. 2 (a) Loading the cavity cell with dilute alkali

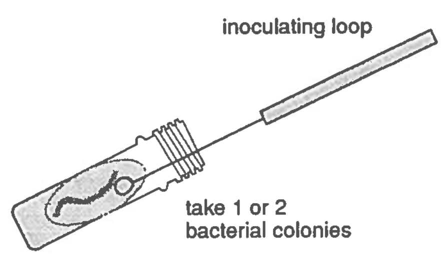


Fig. 2 (b) Aseptic transfer from a slope (or a plate)

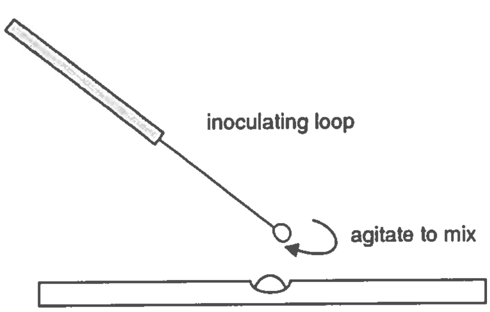


Fig. 2 (c) Gentle agitation of bacterial cells in the alkali

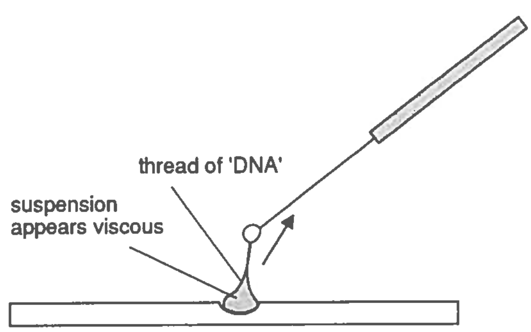


Fig. 2 (d) Drawing up the thread containing DNA

The thread of viscous material is made up partly of bacterial DNA. This indicates that the bacteria under test have lysed, a characteristic of Gram negative organisms. Should the suspension not become viscous and no material is seen to follow the loop, then either too many drops of the hydroxide solution have been used or too much bacterial material has been taken with insufficient time allowed for lysis. If neither were the case and there is still no thread of DNA, then very probably the colony is of a Gram positive organism. *M. luteus*, for example, would yield such a result.

Risk assessments

Possibly the most significant risk in this protocol is that of injury to the eyes of the technician or teacher who makes up the dilute potassium hydroxide solution. At the concentration used by the pupils the alkali is well diluted and the quantity small. Nonetheless eye protection must be worn. As to biohazards and risks; as described, the activity falls within the provisions of the Strathclyde Code (and local variants thereof) for work at Level 3. Given that the Code is an accepted set of General Risk Assessment results, following its provisions is sufficient to meet the requirements of COSHH etc.

The only non-standard bit is the transfer to the potassium hydroxide solution (which Gram negative bacteria are highly unlikely to survive). The restriction of this demonstration to Level 3 - because of the use, and aseptic transfer; of live cells of *E. coli* strains - is however irksome.

Dr Millar has suggested a way round this difficulty. Vegetative cells of bacteria are more readily destroyed by heat than are spores. Exposure to temperatures as low as 60° Celsius will eventually kill many vegetative forms. This is the basis of washing dishes in hot water (detergent aiding and abetting the process). The suggestion therefore is that the plates or slopes be exposed to 60°C for 70 minutes or so. This should effectively kill off all of the bacterial cells in non-spore formers such as the non-pathogenic *E. coli* strains suggested for this application.

It is argued that this treatment leaves only inactive cells, which may be safely handled by pupils of all ages. There is then no need to restrict the DNA demonstration to Level 3 work.

We have trialled this idea and to date it has proved satisfactory. Plates and slopes of *E. coli* were left in a laboratory oven at just over 60° C for the suggested 70 minute period. Although the cells were then dead, their DNA remained intact and could still be extracted as described. Sub-culture was then attempted to see if any of the treated colonies had remained viable. No growth was observed on the plates so inoculated save for on one replicate where there was a fungal contaminant. This was restricted to one colony probably from a single airborne spore.

Acknowledgements

We are most grateful to Dr Robert Millar for taking the trouble to send us an account of this work and to staff at St Andrew's College for encouraging him to do so. Thanks are due also to Dr John Grainger at the National Centre for Biotechnology Education for his comments on this account.

References and further reading

1. *Rapid method for distinction of Gram positive from Gram negative bacteria*, Gregsen, T., European J. Appl. Microbiol. Biotechnol., 5, 23-127, 1978.
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6. *Safety in microbiology : A code of practice for schools and non-advanced further education*, Strathclyde Regional Council, 1989 (and post-16 supplement).

MICROBIOLOGICAL TIPS

In recent months we have had a significant number of technical and safety enquiries on microbiology. This is heartening. School based microbiology seemed at one time to be at death's door. It now looks as though some of the measures taken to clarify and simplify safety requirements as well as to improve training are paying dividends. This is just as well, given some of the requirements of biological courses for Higher Still. Some enquiries suggest that much still remains to be done, especially in further improving the quantity and quality of staff development provision both for teachers and technicians. Putting that broader issue aside, here are three, trustfully useful, sets of tips.

Mouthwash projects: The antimicrobial activity, claimed or implied, of proprietary mouthwashes is becoming a popular topic for projects and investigations. Unfortunately clinically based texts and sources tend to describe procedures using the organisms suspected of being the *in-vivo* causes of gum infections or dental caries. For example, some methods suggest the use of the chief suspect for dental caries - *Streptococcus mutans.* This creates minor difficulty since *S. mutans* is not on any of the so-called approved lists of organisms. That doesn't mean we can't use it. Its use would though entail the carrying out of a formal risk assessment since it isn't covered by any of the published general assessments and controls. Other sources suggest somewhat specialised growth media eg Mitis Salvarius Agar or Todd Hewitt Broth. These can be difficult to obtain in ready made form and their recipes are in fairly obscure sources.

The attention of would be investigators is drawn to an excellent article by Thornton and Terry [1]. They describe work whereby they were able to demonstrate that, for practical educational purposes, in testing claims of antimicrobial efficacy for mouthwashes, we can substitute *Micrococcus luteus* (a.k.a. *Sarcina lutea*) for the usual, clinical, test organism *S. mutans*. In a series of replicate tests, using diffusion zone techniques, both with agar plate wells and filter paper disks, they showed that results for *M. luteus* on ordinary nutrient agar paralleled those for *S. mutans* on more exotic media. In all cases there was little to choose between the two sets of results. *M. luteus* is on the standard educational applications lists and so long as the recommended procedures are followed, the risks should be well controlled[1]. *M. luteus* offers the further advantage of its bright yellow colour, easing the business of spotting any casual contaminants. If you intend growing even *closed* cultures from real saliva, then note that the opportunist pathogen *Candida albicans* - a yeast which can cause the infection thrush - is part of the flora of even healthy mouths.

Reference

1. *Now rinse please : investigating the antimicrobial activity of mouthwashes*, Thornton M. and Terry, J., Journal of Biological Education, 28, (3), Institute of Biology, 1994.

[1] One nit-pick - Thornton and Terry cultured at 37°C, we suggest you use a somewhat lower temperature.

Plooky parallel: Our apologies to those whose delicate sensibilities may be offended - I never could resist a couthy alliteration. The principle of substitution, as just outlined for mouthwash investigations, can also be followed for similar tests with products claiming to control blemishes on teenage skin. Some years ago a kit was made available by Proctor & Gamble, the makers of *Clearasil*. This uses *Staphylococcus albus* (*epidermidis*) alongside our familiar, saffron, friend *Micrococcus luteus* as one of the test organisms (interestingly, both Gram positive cocci).

S. albus is not on the mainstream lists, mainly- one supposes - because of the possibility of easy confusion with strains of the opportunist pathogen *S. aureus*. It is offered by some of the major supply houses, usually under the name *S. epidermidis*. This is not a major problem since, apart from the one reason already indicated, there would seem to be no strong grounds to rule out its educational use. We have had a suggestion[1] that *Staph. albus* be replaced by one of the 'educational' strains of *Bacillus subtilis* (gram positive rods and a spore former). This would not only replace an unlisted organism with a listed one but might also provide a better test of the efficacy of the product(s).

[1] Thanks are due to Jim Stafford (then of Ayr Division, Strathclyde Regional Council) and to Stan Deans at Auchincruive.

Juicy problem: Somewhere on the grapevine a suggestion has been circulating that the fungus *Monilia fructigena* (a.k.a. *sclerotina*) is a useful organism for sixth year projects and practicals. We know - we have had a number of enquiries for the recipe for a strange growth medium known as "V8 agar". No doubt, amongst certain males out there, this conjures up any amount of macho imagery and the ultimate in supercharged Aston Martin ascospores. Nay! 'Tis but a variant on a number of other fruit juice based media such as Tomato Juice Agar. These are used to grow spoilage organisms in commercial labs.

V8 Juice Agar is a richer vegetarian variant of such media. It takes its name from a proprietary brand of vegetable juice as sold in a well known supermarket chain (advertise moi!). Here are two major sub-variants :

Oxoid (Unipath) version :

1 litre V8 vegetable juice; 10g tryptone (Oxoid L42); 5g lactose; 3g meat extract; 15g agar; 1 litre distilled water; adjust pH before autoclaving to pH 5.7.

If (also) looking for lactose fermenting bacilli then add 0.1g of Bromocresol Green per litre as an indicator of lactic acid formation.

International Mycological Institute version :

200 cm^3 of V8 juice; 20g agar; 800 cm^3 distilled water. Adjust pH to 6 (add sodium hydroxide dropwise - care and eye protection needed). After autoclaving at 121°C the pH should fall to ca. 5.8.

When ascospores really are the quarry then a good alternative medium is Cornmeal Agar the recipe for which has been fairly widely published in standard sources such as the Oxoid Manual.

TECHNICAL ARTICLE

MOSFETs

The operation of MOSFETs depends on elementary principles of physics. Factors affecting channel current can be investigated experimentally, from which a mathematical model can be constructed. The model can then be derived theoretically.

Introductory note : The practical work described in this article is undertaken with Chip 2 'The MOS Transistor', one of a set of four teaching chips designed by the Department of Electrical Engineering at Edinburgh University and manufactured by Motorola in Scotland. Please refer to a related article for a description of Chip 2.

MOSFET (Metal-Oxide-Silicon Field-Effect-Transistor) technology is the predominant technology for ICs and has been steadily growing at a rate of over 20% per year for more than a decade. It is the backbone of one of Scotland's biggest industries - micro-electronics. The investigation of MOSFET operation provides scope for the learning and understanding of basic physical concepts such as electric fields, electrostatics, current, electrical properties of materials and atomic theory.

The name *MOSFET* is derived from the method of operation, and the transistor construction. The transistor operates from the effect of the electric fields applied across it (thus, FET); the FET itself is composed of a metal gate deposited on a silicon oxide layer, which is on the surface of a doped silicon substrate. This gives the layering effect of metal upon oxide upon silicon (thus, MOS). At heart, it is a parallel plate capacitor.

Just as there are two types of bipolar transistors (npn and pnp), there are, within the Motorola technology used for these devices, two types of MOSFETs: P-channel and N-channel. The N-channel FET is composed of two heavily doped n-type regions set in a p-type silicon substrate (Fig. 1a) . The n-type regions are known as the *source* and *drain*, depending on the respective potentials (from an external supply). For a conducting FET, the charge carriers enter the channel from the source end and exit at the drain. The charge carriers are electrons for N-channel FETs and holes for P-channel. Thus, the source is more negative than the drain in N-channel FETs (Fig. 1b), and is more positive in the P-channel FETs (Fig. 1c).

The transistor drain and source terminals are interchangeable provided that neither were connected in manufacture to the substrate on which the transistor is built. It is the usual practice to connect the substrate to one of these terminals, defining that terminal to be the source. However, the terminals on some of the transistors on Chip 2 are floating, therefore a more primitive than standard circuit symbol is used in this article (Fig. 2). The diagrams can also be used to define three variables:

V_{GS} = gate potential referenced to the source potential
V_{DS} = drain potential referenced to the source potential
I_{DS} = (conventional) current through channel, from drain to source (N-channel) or source to drain (P-channel)

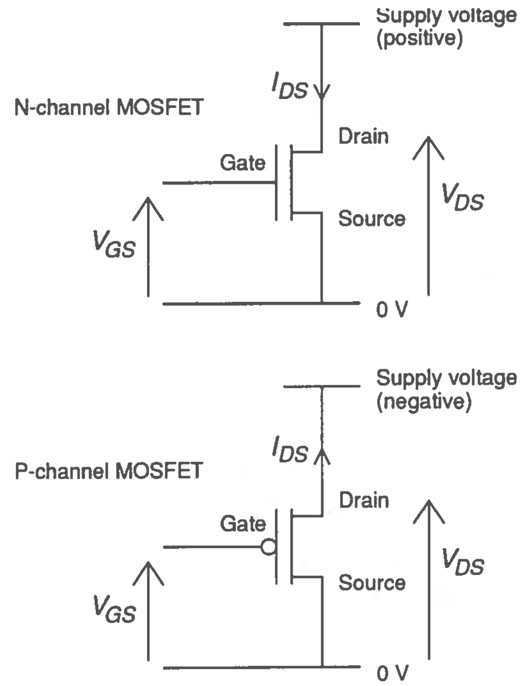

Figure 2. N-channel and P-channel MOSFET symbols as used in this article. These symbols conform with those used in the Teaching Chip manuals, but do not conform to the BS specification.
Note that both gate and drain voltages are referenced to the source.

N-channel and P-channel FETs are complimentary (i.e. their structures and modes of operation are essentially similar, but opposite), and are thus combined on the same chip via CMOS (complimentary MOSFET) processes. The material on which the transistors are built is n-type silicon, known as the substrate. P-channel FETs are built directly onto this n-type substrate, their transistor terminals being the p-type implants. N-channel FETs, however, are built on a well of p-type material implanted into the substrate. The terminals of the N-channel FETs are the n-type implants in this p-well (Fig. 3).

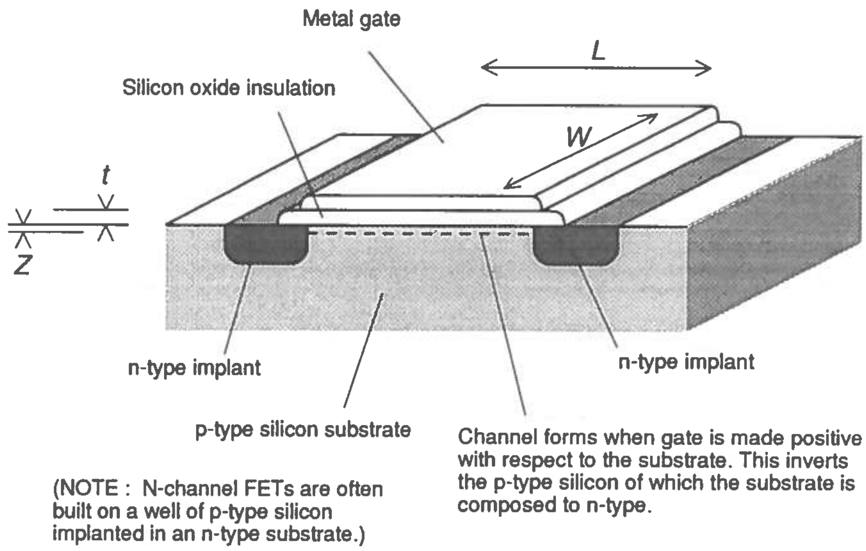

Figure 1a. Simplified schematic diagram of a section through an N-channel metal-oxide-silicon (MOS) transistor showing the structure and types of materials.

Note the symbols defining transistor length L and width W, gate oxide thickness t and channel depth Z, this last quantity being a variable.

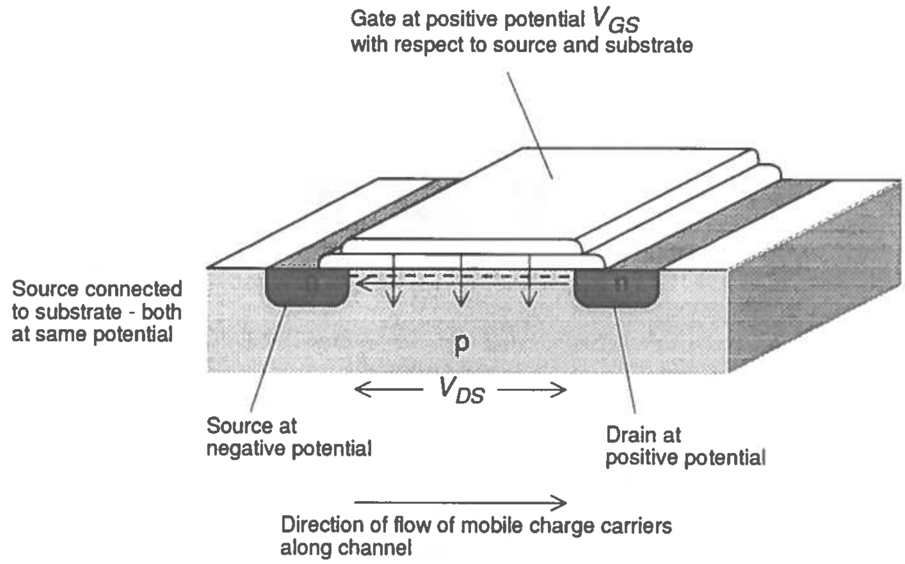

Figure 1b. Simplified schematic diagram of a section through an N-channel MOSFET.

Note that drain and source are interchangeable and are defined by their respective potentials from an external power source.

The arrows in the channel region denote the orthogonal electric fields that apply.

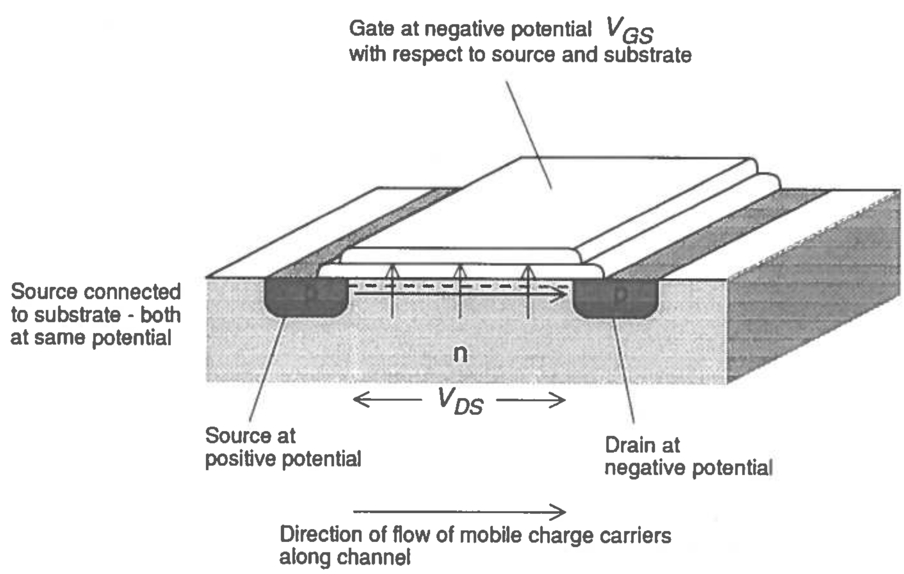

Figure 1c. Simplified schematic diagram of a section through a P-channel MOSFET.

Note that drain and source are interchangeable and are defined by their respective potentials from an external power source.

The arrows in the channel region denote the orthogonal electric fields that apply.

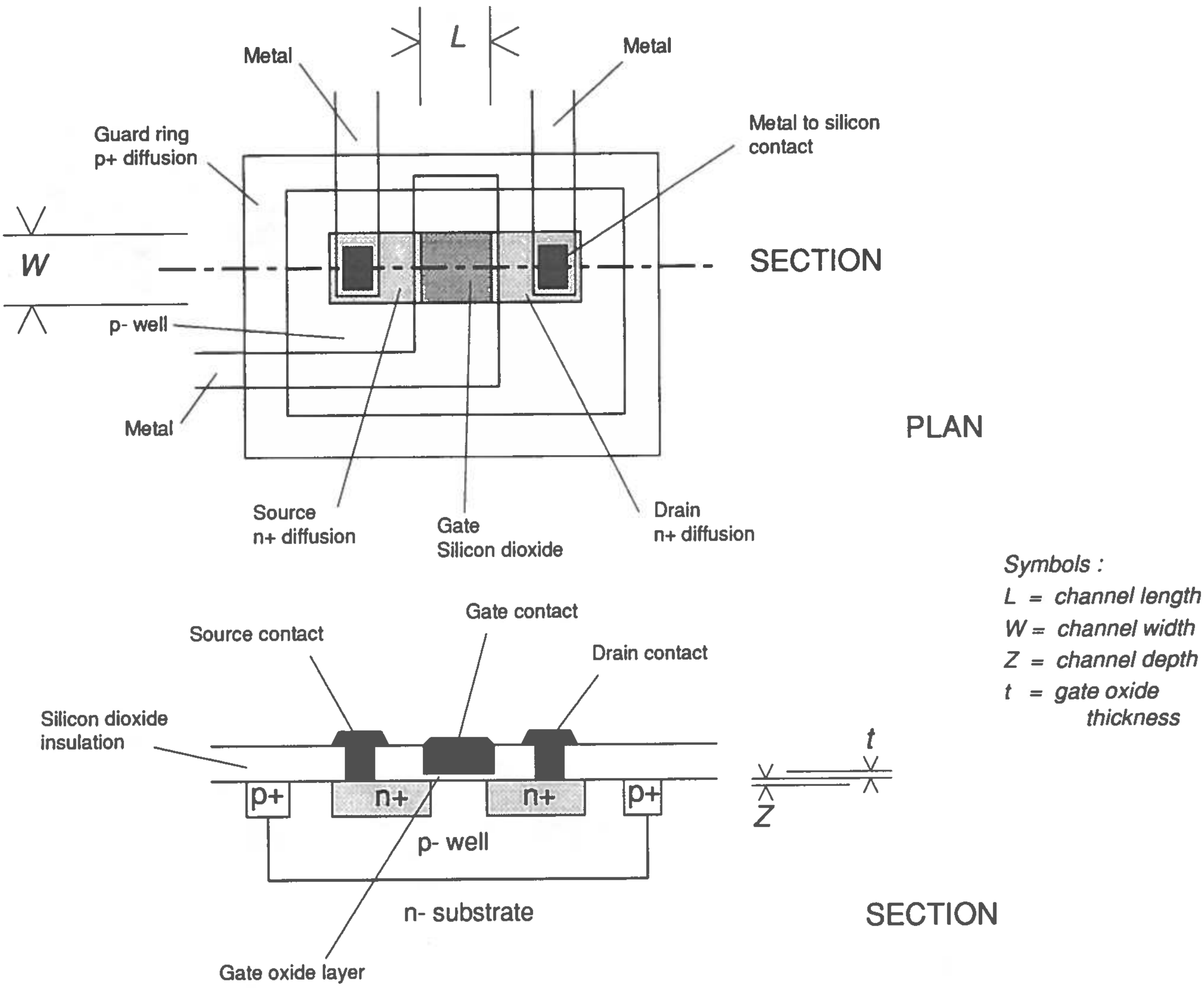

Figure 3. Plan and section views of an N-channel MOSFET on an integrated circuit. Whereas P-channel MOSFETs would be built directly on the n-type substrate on which all of the i.c.'s structures would be constructed, N-channel transistors are built on a well of p-type material implanted into the substrate. N+ represents heavily doped n-type material; p- represents lightly doped p-type stuff. They do not stand for strange versions of electric charge!

Transistors are often drawn in both section and plan (Fig. 3). Both are needed to show how the implants and layers of surface structures relate. One of the purposes of this article is to illustrate how electrical properties depend on size, shape and position. The enquiring student is thereby led into considering the particulate nature of matter and the movement of charge carriers through materials.

Operation

The analysis of MOSFETs below will refer to N-channel FETs, but a similar description can be made for P-channel.

MOSFETs operate by forming a conducting channel at the surface of the p-well just below the oxide, between the drain and source pins. If the gate is at zero potential ($V_{GS} = 0$) the circuit between drain and source is equivalent to a pair of back to back diodes (Fig. 4). If a potential difference V_{DS} is applied between the drain and source terminals, there is no conduction of current ($I_{DS} = 0$). The transistor is said to be *switched off*.

A conducting channel is formed by applying an electrostatic field between the gate and well. (Remember that the gate forms a capacitor, which charges according to $Q = C\,V$.) Consider just the section through the gate and p-well (Fig. 3). For a zero gate potential, a heavily doped p-type region exists at the surface of the p-well. As the p-well is composed of p-type material, the majority carriers are positive holes, and the minority carriers are electrons.

Applying a positive gate potential causes the majority carriers to be repelled from, and the minority carriers to be attracted to, the surface of the p-well. This process is

Figure 4. Equivalent source to drain circuit for a switched-off, N-channel MOSFET.

called *inversion*. For low gate potentials there is weak inversion at the p-well surface; the operation of FETs in this mode is called *subthreshold operation*. If V_{GS} is increased further, the surface becomes fully inverted, a channel of n-type material exists between the drain and the source; the value of gate potential at this point is known as the *threshold potential* V_T. For gate potentials greater than the threshold potential, the channel becomes strongly inverted, with an excess of the negative charge in the channel. This negative charge is composed of both fixed and mobile charge carriers.

Applying a potential difference between the drain and the source provides another electric field, crossed with the gate field (Fig. 1b), which drives the mobile carriers through the channel from source to drain, i.e. a current exists. This is the basis of MOSFET operation.

The FET operation can be examined by obtaining I_{DS} values for a range of V_{GS} and V_{DS}. Doing this for both large and small values of V_{DS} (in comparison to V_{GS}) should give interesting results.

Linear operation

The following experiments on linear operating conditions were all carried out with $V_{DS} \ll V_{GS}$. The same circuit (Fig. 5) is used throughout. V_{GS} is controlled by adjusting the 10 kΩ pot; V_{DS} is controlled by adjusting the 2 kΩ one. Because V_{DS} needs fine control, we recommend that the 2 kΩ pot is multiturn. Three digital multimeters were used. Measurements were made on all four N-channel FETs on Chip 2; the respective gate widths W vary in the ratio 1:2:4:8.

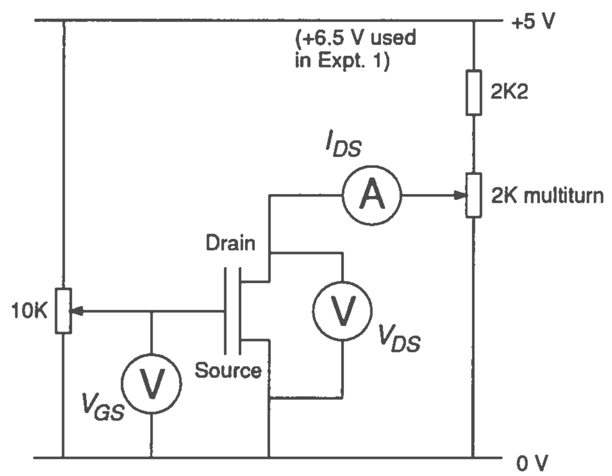

Figure 5. Circuit diagram for experiments on linear operating conditions on an N-channel MOSFET.

1. Drain current versus drain voltage

The experiment. The dependence of I_{DS} on V_{DS} was investigated keeping V_{GS} constant (in our case V_{GS} = 6.5 V although a value of 5.0 V might be more convenient and would also be very suitable). The value of V_{DS} was not taken above 700 mV.

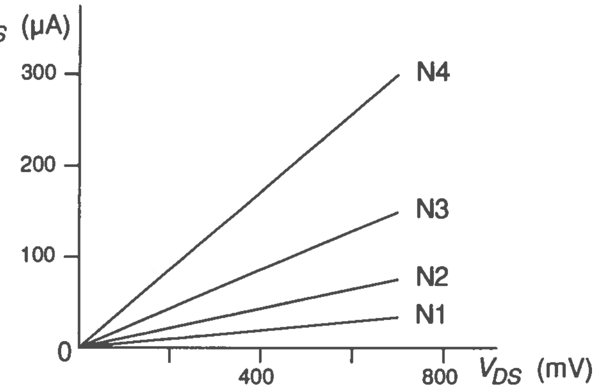

Figure 6. Dependence of drain current on drain voltage for $V_{DS} \ll V_{GS}$. Graphs drawn for four different transistors.

The findings. I_{DS} varies directly with V_{DS} (Fig. 6).

The gradients of I_{DS} / V_{DS} for the four transistors N1 to N4 vary in the ratios 1:2:4:8. Thus gradient corresponds with channel width. (This finding is discussed in Experiment 3.)

The analysis. The channel behaves like an Ohmic resistor. However rather than describe this behaviour in a mathematical form similar to Ohm's Law, viz.

$$V_{DS} = R_{DS} I_{DS}$$

we will express current as a function of voltage :

$$I_{DS} = k' V_{DS}$$

where k' is a constant, with no attempt at this stage to introduce the term 'conductance'.

2. Drain current versus gate voltage

The experiment. The dependence of I_{DS} on V_{GS} was investigated keeping V_{DS} constant (V_{DS} = 100 mV). The value of V_{GS} was varied from 0 V to 5 V.

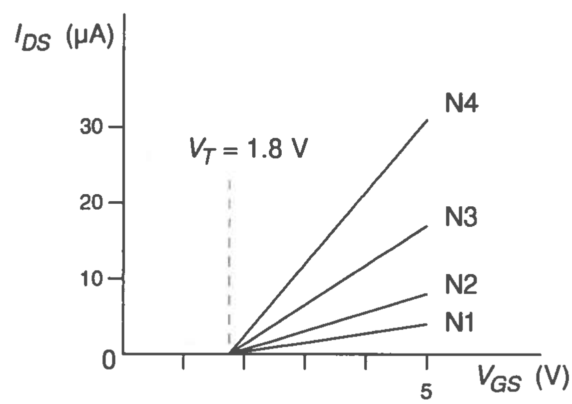

Figure 7. Dependence of drain current on gate voltage for $V_{DS} \ll V_{GS}$. Graphs drawn for four different transistors.

The findings. There is a threshold voltage V_T below which $I_{DS} = 0$. All the N-channel transistors on the same chip have the same value of threshold voltage, about 1.76 V.

For $V_{GS} > V_T$, I_{DS} varies directly with $(V_{GS} - V_T)$ (Fig. 7).

The gradients of $I_{DS} / (V_{GS} - V_T)$ for the four transistors N1 to N4 vary in the ratios 1:2:4:8. Thus gradient corresponds with channel width. (This finding is discussed in Experiment 3.)

The analysis. The process of inverting the heavily doped material beneath the oxide layer to form the channel is the cause of the threshold effect.

The threshold potentials are of the same value for each of the four FETs because they are composed of the same type of material and because their gates all have the same thickness of oxide.

The channel depth increases linearly with $(V_{GS} - V_T)$. If the channel deepens, its resistance lessens, just as happens when you connect resistors in parallel. We can model this mathematically :

$$I_{DS} = k''(V_{GS} - V_T) \qquad \text{where } k'' \text{ is a constant}$$

3. Drain current versus channel width

The experiment. Data on this relationship was collected in the first experiment. Values of I_{DS} were plotted against channel width W for $V_{GS} = 6.5$ V and $V_{DS} = 700$ mV.

The finding. Drain current is proportional to channel width (Fig. 8) when comparing the operation of different transistors.

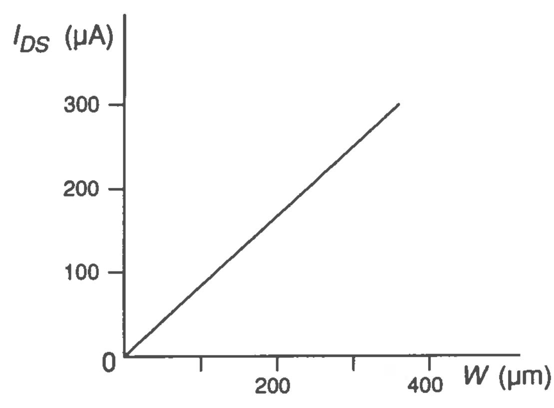

Figure 8. Dependence of drain current on channel width for $V_{DS} \ll V_{GS}$. Graph drawn from four different transistors: N1 to N4.

The analysis. Because the channel behaves like resistor material, when its width doubles its resistance halves. We can model this mathematically :

$$I_{DS} = k''' W \qquad \text{where } k''' \text{ is a constant}$$

4. Drain current versus channel length

The experiment. This is a thought experiment. Because all of our transistors have the same channel length, we are not able to experiment with this property.

If however we had a sample of transistors with different channel lengths, then how would the drain current depend on channel length, all other conditions being the same?

The expectation. The drain current would be inversely proportional to channel length for different samples of transistors.

The reasoning. Because the channel behaves like resistor material, its resistance should be proportional to length. We can model this mathematically :

$$I_{DS} = k''''(1 / L) \qquad \text{where } k'''' \text{ is a constant}$$

Summary of experiments

A mathematical model can now be constructed which summarises all the experiments :

$$I_{DS} = k\,(W/L)\,(V_{GS} - V_T)\,V_{DS} \qquad 1$$

The results and model are explained by thinking of the channel as a collection of resistors (of equal value) connected in parallel or in series (Fig. 9). Increasing V_{GS} increases the inversion, thus increasing the channel depth Z. This can be modelled by connecting more resistors in parallel, thus decreasing the resistance and increasing the current. Similarly for the channel width W, increasing width increases current - this again is modelled by connecting more resistors alongside. However the opposite effect occurs when resistors are added in series. Resistance increases with length L, causing current to be reduced.

The final part of the model relates to the effect of the electric field along the channel length. Increasing V_{DS} drives charge carriers through the channel at a greater rate, thus current is increased.

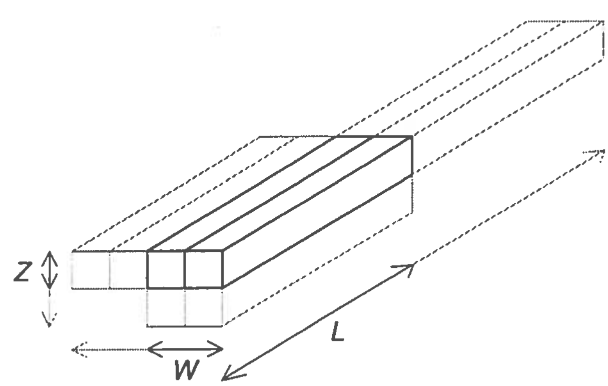

Figure 9. Channel model comprising of strips of material having electrical resistance. Increasing channel depth or width is equivalent to connecting further resistors in parallel. Increasing channel length is equivalent to adding resistors in series.

It is useful to relate channel resistance R_{DS} with its geometrical properties using the standard formula :

$$R_{DS} = (\rho L) / A = (\rho L) / (W Z)$$

where ρ is resistivity, L is channel length, A is the cross sectional area of the channel of width W and depth Z.

The dependence of channel current on the aspect ratio of MOSFETs follows from this equation and the Ohm's Law expression for current :

$$I_{DS} = (1 / R_{DS}) V_{DS}$$

$$I_{DS} = (W Z V_{DS}) / (\rho L)$$

$$I_{DS} = \sigma Z (W / L) V_{DS} \qquad 2$$

which resembles part of Equation 1 (σ (= $1/\rho$) is channel conductivity). Equating terms, it follows that :

$$\sigma Z = k (V_{GS} - V_T)$$

It would seem reasonable to infer that channel depth depends on gate voltage and that conductivity depends on the factor k, which presumably is a function of the electrical properties of the channel materials. We will return to this in our theoretical model later in the article.

Non-linear operation

We have shown that the drain current is linearly dependent on V_{DS}, $(V_{GS} - V_T)$ and W for very small values of V_{DS}. We will now remove this constraint and look at the behaviour for any value of V_{DS}.

5. Drain current versus gate voltage

The experiment. The dependence of I_{DS} on V_{GS} was investigated keeping V_{DS} constant at 10 V using the circuit shown (Fig. 10). As before, all four N-channel transistors were looked at.

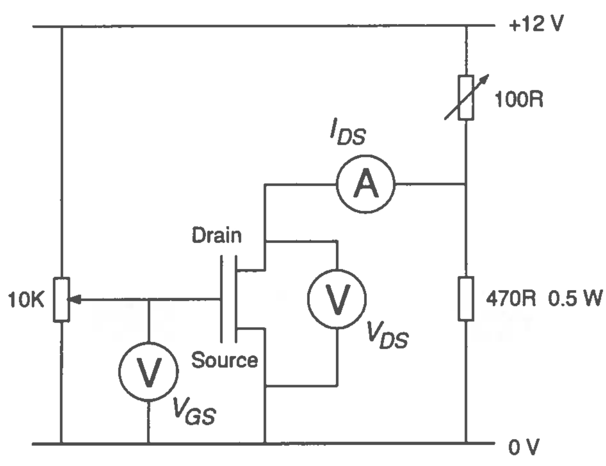

Figure 10. Circuit diagram for investigating the non-linear dependence of drain current on gate voltage. Drain voltage maintained constant at 10 V by fine adjustments to the 100 Ω rheostat.

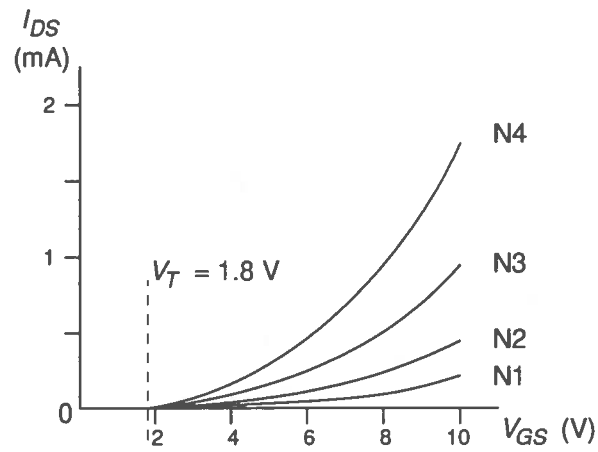

Figure 11. Dependence of drain current on gate voltage for V_{DS} = 10 V. Graphs drawn for four different transistors.

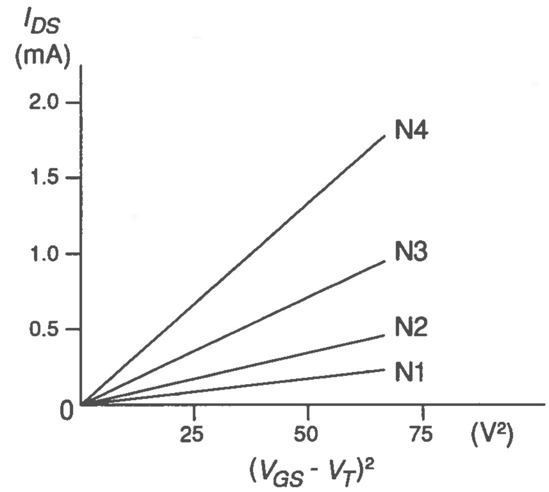

Figure 12. Dependence of drain current on $(V_{GS} - V_T)^2$ for V_{DS} = 10 V. Graphs drawn for four different transistors.

The findings. The curve of this graph (Fig. 11) suggests a quadratic relationship. To confirm this, values of I_{DS} were plotted against $(V_{GS} - V_T)^2$ (Fig. 12), which reveals straight line relationships.

The gradients of $I_{DS} / (V_{GS} - V_T)^2$ vary in the ratios 1:2:4:8, corresponding to the channel widths of the four transistors.

Analysis. We can describe the drain current by the following expression :

$$I_{DS} = k' W (V_{GS} - V_T)^2$$

where k' is a constant (the constant k' used here is not the same as the one used in the linear case).

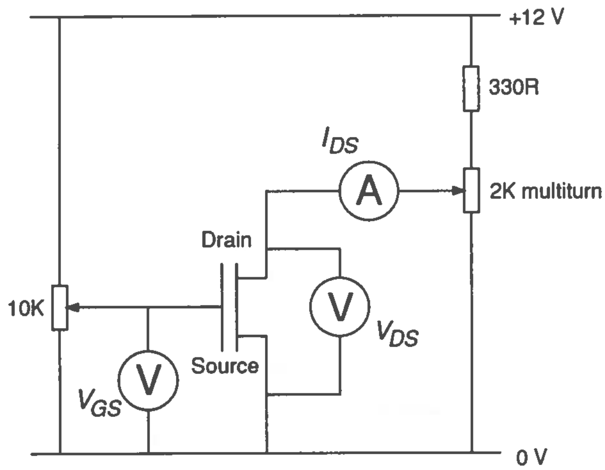

Figure 13. Circuit diagram for investigating the non-linear dependence of drain current on drain voltage using transistor N4 for three values of gate voltage.

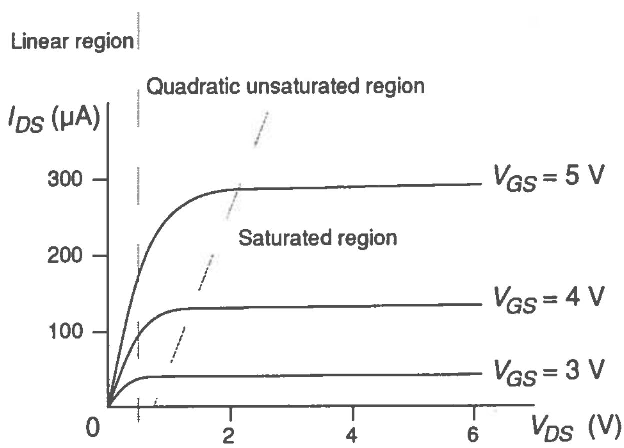

Figure 14. Dependence of drain current on drain voltage for V_{GS} = 3 V, 4 V and 5 V (measured on transistor N4).

6. Drain current versus drain voltage for three gate voltages

The experiment. The dependence of I_{DS} on V_{DS} was investigated for several set values of V_{GS} (3 V, 4 V and 5 V) (i.e. V_{GS} was maintained at 3 V etc. while V_{DS} was varied from 0 V to 10 V). The circuit is shown in Figure 13.

The findings. The linear operating region holds only for $V_{DS} \ll (V_{GS} - V_T)$ For intermediary values of V_{DS} there is a quadratic relationship. For large values of V_{DS}, drain current is independent of V_{DS} (Fig. 14).

The analysis. FETs act as constant current devices when the drain voltage is comparable to, or greater than, $(V_{GS} - V_T)$. This can be explained by thinking of the electric fields that affect the channel. For $V_{GS} < V_T$ the channel is not formed, so there will be no conduction. If the potential of the drain equals, or is greater than, $(V_{GS} - V_T)$, then the channel is pinched off near the drain preventing the inversion in that locality (Fig. 15).

The channel is a region of mobile charges. If the potential of the drain increases, the depletion region surrounding the n-type implant that constitutes the drain gets larger. It spreads out under the gate where the channel would be. Mobile negative charge near to the drain gets swept into the drain by the strong electric field. This largely destroys the channel under the drain end of the gate making it more difficult for charge carriers to pass through the channel.

Once pinch-off occurs, it is the pinched off region which defines channel resistance, ensuring a constant current whatever the value of drain voltage.

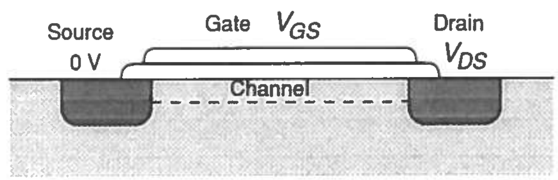

Figure 15a. $V_{DS} \ll (V_{GS} - V_T)$: Depth of channel uniform across length.

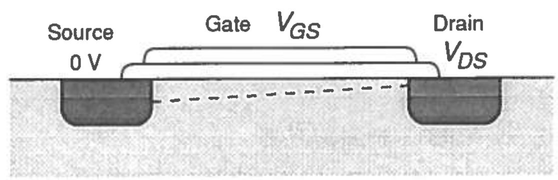

Figure 15b. $V_{DS} < (V_{GS} - V_T)$: Depth of channel narrows towards drain.

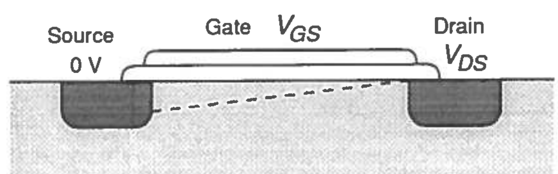

Figure 15c. $V_{DS} = (V_{GS} - V_T)$: Channel pinched off at drain.

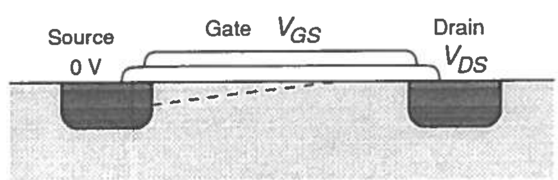

Figure 15d. $V_{DS} > (V_{GS} - V_T)$: Channel pinched off under gate and becomes extremely narrow between this point and the drain.

I_{DS} (µA)	V_{GS} (V)	$(V_{GS} - V_T)$ (V)	$(V_{GS} - V_T)^2$ (V^2)	$I_{DS} / (V_{GS} - V_T)^2$ (µA / V^2)
289	5.0	3.2	10.24	28
136	4.0	2.2	4.84	28
40	3.0	1.2	1.44	28

Table 1. Values of saturation current against gate voltage for transistor N4. Quotient of current against the square of the voltage is constant, in agreement with Equation 3. Note that V_T is 1.8 V.

The transistor is said to be *saturated* when current is independent of drain voltage.

The mathematical model for this region does not therefore contain the term V_{DS}. The model is :

$$I_{DS} = k\,(W/L)\,(V_{GS} - V_T)^2 \qquad 3$$

where k is a constant and L is channel length (introduced for the same reason as the linear case).

The values (Table 1) for saturated currents graphed in Figure 14 conform with the quadratic relationship between I_{DS} and $(V_{GS} - V_T)$.

Theoretical model

Having concluded our experimental investigations into factors affecting drain current, we have derived by empirical means two mathematical models. Equation 1 models the linear operating region; Equation 3 models the saturated operating region. A theoretical derivation is now shown.

Model of linear operation

Because the channel behaves like a resistor, we can apply Ohm's Law to write an expression for current :

$$I_{DS} = (1 / R_{DS})\,V_{DS} \qquad 4$$

From the definition of resistivity :

$$R_{DS} = (\rho\,L) / A$$

$$= (\rho\,L) / (W Z)$$

$$= L / (\sigma\,W Z) \qquad 5$$

where ρ is channel resistivity, σ is channel conductivity, L is channel length, A is channel cross-sectional area, W is channel width and Z is channel depth.

Substituting 5 into 4 gives :

$$I_{DS} = (\sigma\,W Z\,V_{DS}) / L \qquad 6$$

Conductivity is related to the number of mobile charges per unit volume n, electric charge of charge carrier q and mobility of charge μ by :

$$\sigma = n\,q\,\mu$$

The total charge Q on the channel is the product of charge density and channel volume :

$$Q = (n\,q) \times (W L Z)$$

Therefore $\quad n\,q = Q / (W L Z)$

Therefore $\quad \sigma = (Q\,\mu) / (W L Z) \qquad 7$

Substituting 7 into 6 :

$$I_{DS} = (Q\,\mu\,V_{DS}) / L^2 \qquad 8$$

From the definition of capacitance, where K is the oxide relative permittivity and t is the oxide thickness :

$$Q = C\,V_{GS}$$

$$Q = (K\varepsilon_0\,A\,V_{GS}) / t$$

$$Q = (K\varepsilon_0\,W L\,V_{GS}) / t \qquad 9$$

Substituting 9 into 8 gives :

$$I_{DS} = [(K\varepsilon_0\,\mu) / t\,]\,(W/L)\,V_{GS}\,V_{DS}$$

$$I_{DS} = \beta\,(W/L)\,V_{GS}\,V_{DS} \qquad 10$$

where $\beta = (K\varepsilon_0\,\mu) / t$

The factors within the β term are usually standardized by the semiconductor manufacturer. Therefore the factors which the chip designer plays about with are gate width and length. However as we shall see later the mobility μ is not constant.

The region where the channel is formed in the substrate is extra-heavily doped. Because of this, the channel does not form by the inversion process until the gate voltage exceeds a threshold value V_T (Fig. 16). In the expression for drain current, the term V_{GS} should therefore be replaced by $(V_{GS} - V_T)$ to become :

$$I_{DS} = \beta\,(W/L)\,(V_{GS} - V_T)\,V_{DS} \qquad 11$$

This is the mathematical model for drain current in the linear, or unsaturated, working region of a MOSFET. It agrees with Equation 1, found by experiment.

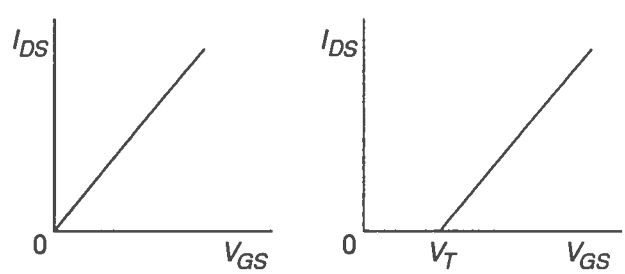

Figure 16. Linear dependence between drain current and gate voltage offset by threshold voltage.

Model of non-linear operation

As V_{DS} increases, the relation becomes less linear. A simple linear correction can be made by taking the average channel potential to be (V_{GS} - ½V_{DS}); i.e. replacing V_{GS} by (V_{GS} - ½V_{DS}).

This correction changes the expression for drain current from a linear to a quadratic function :

$$I_{DS} = \beta (W/L) [(V_{GS} - V_T) - \tfrac{1}{2}V_{DS}] V_{DS} \qquad 12$$

Saturation occurs at the limit :

$$dI_{DS} / dV_{DS} = 0$$

i.e. where current is constant for high values of V_{DS}.

This is true only if $V_{DS} = V_{GS} - V_T$

Substituting this in 9 gives :

$$I_{DS} = \tfrac{1}{2}\beta (W/L) (V_{GS} - V_T)^2 \qquad 13$$

This is the model for drain current in the saturated region. It agrees with Equation 3, found by experiment.

It should be clear that Equation 12 is generally applicable for both linear and non-linear conditions. This indeed is the general equation for deriving MOSFET drain current. It should also be clear that the constants k used in the empirical relationships 1 and 3 are identical to β and ½β respectively.

Acknowledgements

The material used in this article was prepared by a 19-year old temporary researcher at SSERC, Stevaan Hall. Stevaan spent his summer vacation working in the Centre under the direction of a senior member of staff. A former pupil of Dyce Academy, he is now in his third year at Edinburgh University, where he is studying mathematical physics.

As the first draft of this article was written by Stevaan, he may rightly be recognised as a joint author.

The Centre is grateful to the University of Edinburgh Teaching Chip Steering Group for funding Stevaan's vacation work. Dr Les Haworth, who chairs the Group, has kindly read through the article and made some helpful contributions.

Further reading

The following publications were consulted in the preparation of this article.

1. *Teaching Support Material Semiconductor Teaching Chips* Volume 1, J Robertson, University of Edinburgh and Teaching Chip consortium.
2. *An introduction to CMOS devices*, Advanced VLSI Training Modules, Volume 10, COMETT 3577 Cb, J Robertson, University of Edinburgh.
3. T M Frederiksen, *Intuitive IC Electronics*, National's Semiconductor Technology Series, McGraw-Hill, New York, 1982, ISBN 0 07 021923 0.
4. P Horowitz, W Hill, *The Art of Electronics*, Cambridge UP, Cambridge, 1989, ISBN 0 521 37095 7.
5. W Bolton, *Electrical and Magnetic Properties of Materials*, Longman, Harlow, 1992, ISBN 0 582 07025 2.

Appendix : P-channel MOSFETs

The use of P-channel MOSFETs is briefly described. The circuits shown here are complements of the one in Figure 5, which had an N-channel transistor.

You may either work with a negative supply rail (Fig. 17), which has the advantage that the source and voltages are referenced to the 0 V rail, or you may use a positive supply rail (Fig. 18), inverting everything in the circuit. This second arrangement is necessary with Chip 2 so as to correctly bias the p-well and substrate.

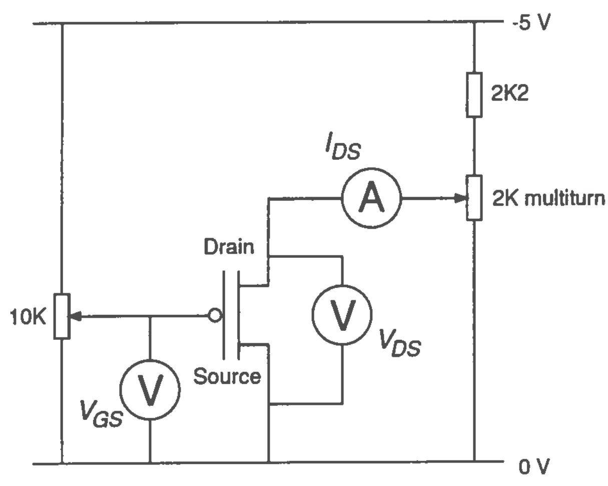

Figure 17. Circuit diagram for experiments on linear operating conditions on a P-channel MOSFET. Note that this circuit arrangement has a negative supply.

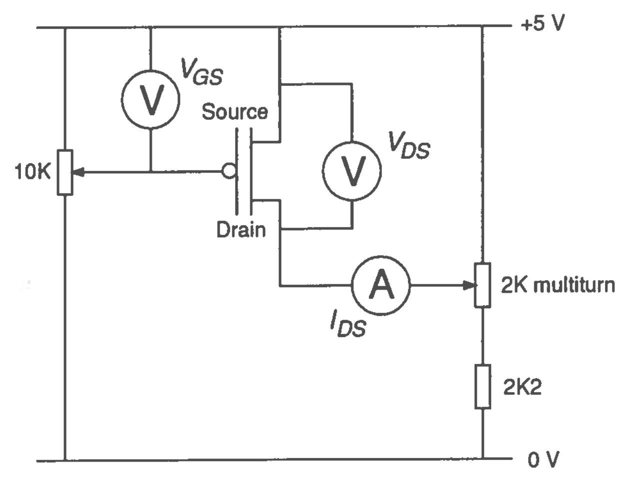

Figure 18. Circuit diagram for experiments on linear operating conditions on a P-channel MOSFET using a positive supply. Note that voltages are referenced to the positive supply rail, to which the source is connected.

TECHNICAL ARTICLE

Description of Chip 2 : The MOS Transistor

Practical work in the previous article was carried out on Chip 2 of the Edinburgh University Teaching Chip set. Here we provide the specification of Chip 2 and give some tips on handling.

Chip 2 contains four N-channel transistors and four P-channel transistors. The transistors have different aspect ratios which relate by simple proportion (Fig. 1) (Table 1).

The chip is housed in a 16-pin DIL package composed of a clear epoxy. The chip itself is therefore visible. Individual transistors are discernible - I am assured by good-sighted youngsters. They may be more comfortablv seen by microscope.

The manner by which transistors are interconnected is shown in Figure 2.

The following points relate to usage :

1. So as to fit all eight transistors in a 16-pin DIL package, all of the transistors are interconnected; none stands isolated. All of the transistors may be used in isolation as individual devices. However when planning to work with two or more transistors, certain combinations cannot be made.
2. The four P-channel transistors are built directly upon the N-type substrate. Pin 16 is bonded directly to the substrate. Pin 16 is also connected to P2 and P3.
3. The four N-channel transistors are built upon a P-well within the substrate. Pin 8 is bonded electrically to the P-well. Transistors N2 and N3 also connect to pin 8.
4. The polarities of drain and source are interchangeable on transistors N1, P1, N4 and P4. These polarities depend on the polarities of external supplies connected to these transistors and are set by the user.
5. The polarities of N2, P2, N3 and P3 are fixed by the substrate and P-well contacts. Pin 8 must always be at a negative potential and must thereby define the sources of N2 and N3. Pin 16 must always be at a positive potential and must similarly define the sources of P2 and P3.

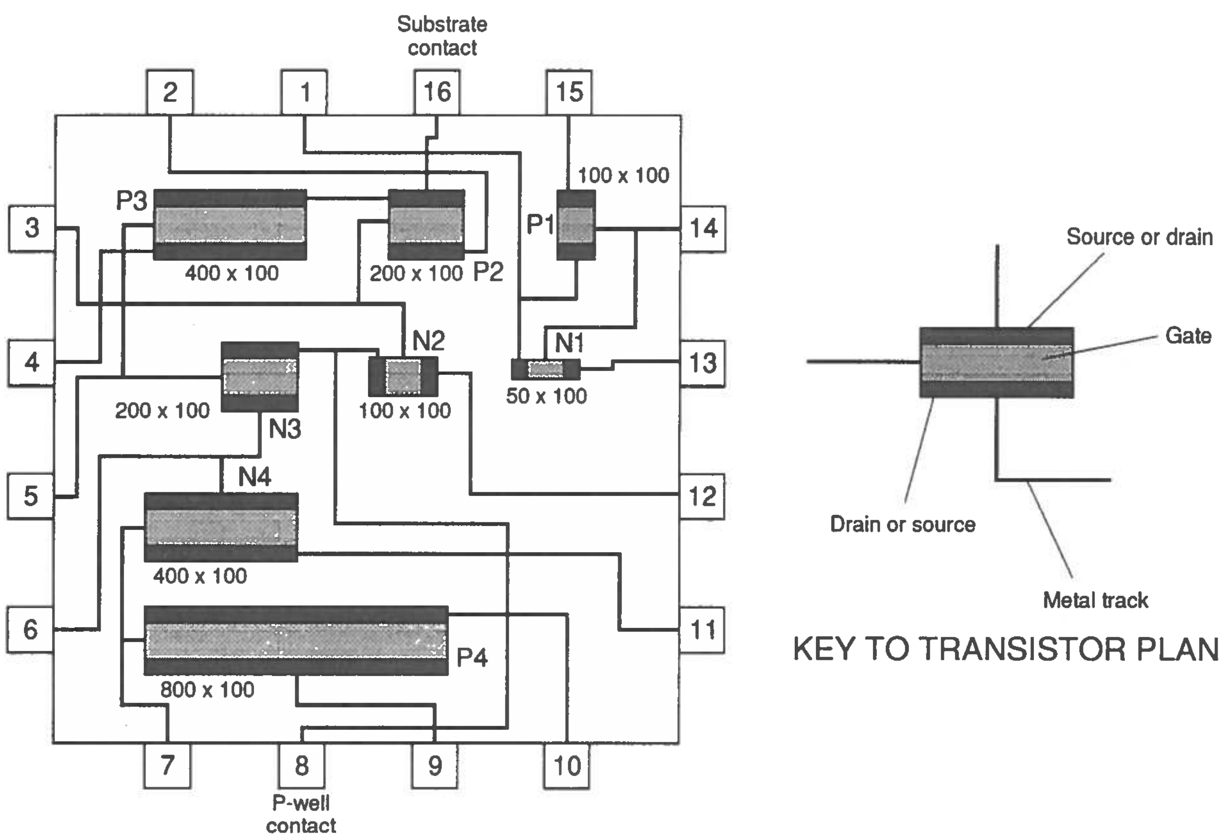

Figure 1. Plan of Chip 2 showing aspect ratios of transistors. Dimensions are in microns (μm).

6. Extreme voltage limits are not known, but would seem to lie in excess of 15 V. We recommend that you do not go above this value.
7. In any circuit work, always connect the negative of the supply to the P-well contact (pin 8) and the positive of the supply to the substrate contact (pin 16). Do this even when you are not using transistors directly connected to these pins.
8. Never attempt to apply a voltage to any of the transistors at a potential lower than that which you have placed on pin 8. Pin 8 must always be at the minimum voltage of any electrical system.
9. Never attempt to apply a voltage to any of the transistors at a potential above that which you have placed on pin 16. Pin 16 must always be at the maximum voltage of any electrical system.
10. Light dependent currents can be induced within transistors N4, P2 and P3. (Note : such currents are generated whenever light falls on any p-n junction. There are lots of p-n junctions within the structures on Chip 2. The package encapsulating the chip is transparent.)
11. The transistor most greatly affected by light dependent currents is N4. This occurs when pin 11 is the source and pin 6 is the drain. A current of nearly 200 µA may be produced. Ways of avoiding this effect are :

    - changing the polarity of N4 by making pin 6 the source and pin 11 the drain, or

    - covering the chip with blackout, or

    - connecting the gate of N3 (pin 5) to 0 V (or to the same potential as is on the P-well contact).
12. Light dependent currents of the order of 20 µA may affect P2 or P3. It is not possible to prevent these currents by electronic means. The only effective cure is blackout.
13. Although as a general rule whenever working with MOS devices every unused input should be tied either high or low, this precaution is not needed when using Chip 2. Any transistor, or set of transistors, may be used in isolation. All other transistors can be left floating. However pins 8 and 16 always need to be tied (see point 7) and pin 5 sometimes should be tied (see point 11).
14. The maximum power rating is 1 W.

Stocks of the Edinburgh University Teaching Chip set are available for purchase from SSERC by schools and colleges in Scotland. The price of £4.00 for the set of four chips includes breadboard and covers post and packing.

Transistor number	W (µm)	L (µm)	V_T (V)	R_{DS} (kΩ)
N1	50	100	1.8	140
N2	100	100	1.8	70
N3	200	100	1.8	35
N4	400	100	1.8	17
P1	100	100	1.05	87
P2	200	100	1.05	43
P3	400	100	1.05	21
P4	800	100	1.05	10

Table 1. Transistor properties.

NOTE :
V_T is the value of V_{GS} at I_{DS} = 10 µA and V_{DS} = 200 mV
R_{DS} is measured at V_{GS} = 5 V and V_{DS} = 5 V

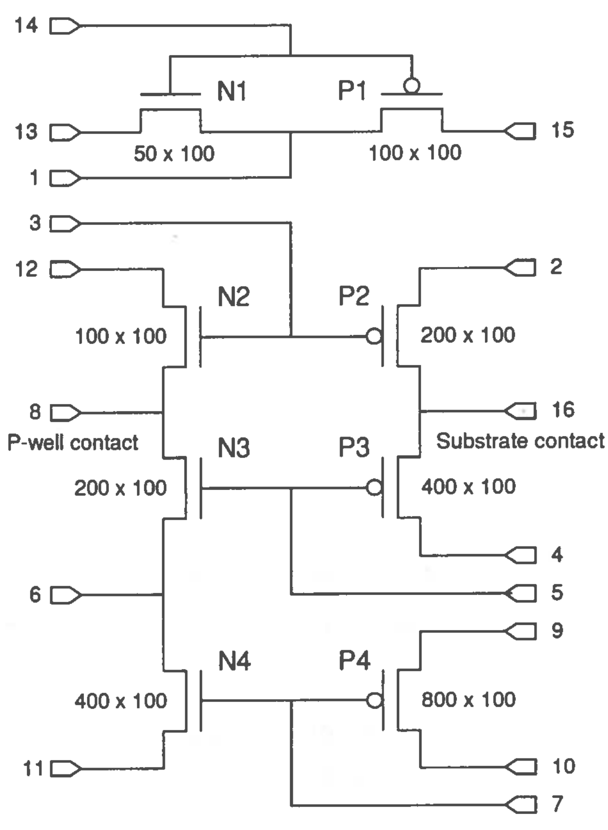

Figure 2. Circuit diagram of Chip 2 showing interconnections of transistors. Gate dimensions are in microns (µm).

TECHNICAL TIPS

Unilab Timing Ball

The Timing Ball (Unilab order code 513.060 - now removed from Unilab's product range), which is about the size of a cricket ball and has a stitched, synthetic leather cover, has a digital stopclock embedded within it with which to measure its time of flight. The trouble is that the battery, which has an expected lifespan of 5 years, is not supposed to be replaceable. However John Muir, PT Physics at St Margaret's School, Livingston, knows better. He phoned to tell us how the battery can be replaced. We have tried it out for ourselves and will give you the details :

1. Opposite to the clock display, underneath the legend "Speedgun Ball", start unstiching the leather. Work along the seam in both directions from the legend until about 5 mm past the edge of the clock on both sides of the clock.
2. The leather should lift up easily; pull the clock out, having first removed its cover.
3. Remove the foam pad from the rear of the clock module and undo three screws securing the battery. Replace the battery (Type CR2032, Farnell 300-445), which is a lithium cell.
4. Reassemble the parts. The leather flap may be glued down, or restitched. Otherwise cover the broken stitching with tape.
5. The used lithium cell should be covered with insulating tape to prevent shorting and disposed of with ordinary refuse. Your attention is drawn to the warnings on handling lithium cells we recently published [1].

Reference

1. *Lithium cells*, Bulletin 185, SSERC, Summer 1995, p12.

Electricity generation

We recently had a request from a teacher to devise a simple means of showing how electricity might be generated by steam. The teacher specifically did not want to attach a propeller or turbine to a small motor because he felt that the motor resembled black box mumbo jumbo which did not illustrate the underlying physical principle.

The model described here illustrates most of the process, but substitutes an air flow from a blower for steam.

The parts are all easily available - some from SSERC Surplus. An aluminium shaft from a Westminster electromagnetism kit is supported horizontally in the usual way by two split pins fitted to a support base. Two turns of insulating tape are wrapped around one end of the shaft to increase its girth and a three bladed propeller made from a SSERC propeller kit (item 792) is mounted

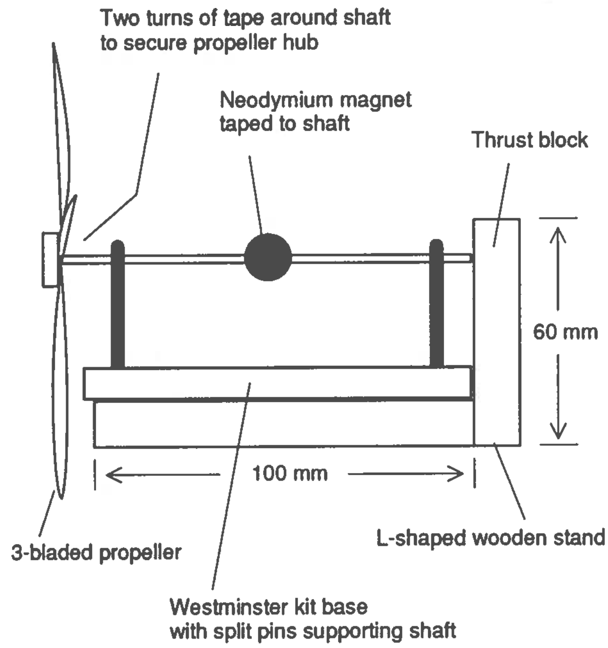

Figure 1. Section through generator showing most of the parts. The C-core with coil sits on the horizontal section on the L-shaped stand adjacent to the magnet.

over it. A neodymium magnet (SSERC item 771) is fastened by insulating tape to the centre of the shaft. This choice of magnet is important. Because the magnet is quite tiny, it has a very small moment of inertia when fitted to the shaft, which therefore can be turned with ease. Secondly, because the magnet is remarkably strong, it can readily generate a voltage in a coil.

A thrust block is required to prevent the propeller shaft from moving horizontally in the air stream. Two small strips of wood were pinned together to give an 'L' cross-section. The Westminster kit base should be placed on the horizontal strip with the shaft touching the vertical strip, which takes the thrust (Fig. 1). The whole assembly should be sat on a small stand, such as a tripod, to which it should be secured with a small G-clamp.

The L shaped support should be sufficiently large to accommodate a C-core from a Westminster kit. With about 60 turns of wire on the C-core, we found that, by playing a moderate airstream on the propeller, about 10 mV a.c. was generated. If a 2400 turn Unilab coil is substituted, then 800 mV a.c. and 100 mV a.c. are generated with and without the C-core respectively.

The effect of loading the generator can be shown. A 1 kΩ load does not perceptibly slow the rotation with the 2400 turn coil; however a 33 Ω load certainly does.

Fehling's - an even safer substitute

In this note the hazards and risks attendant on the use of Fehling's solutions in testing for reducing sugars and some other reducing agents are discussed. Three safer substitutes are suggested : Benedict's Reagent, Barfoed's Reagent and one described more recently by Sandell [1].

The recipe for Fehling's solution was published in 1848 [2]. It still provides an effective means of distinguishing between certain reducing and non-reducing sugars as well as between alkanals and alkanones. However it is strongly alkaline and highly corrosive. Fehling's solution B is equivalent to a sodium hydroxide solution of almost 4M. The more dilute reagent made just before use in mixing equal volumes of Solutions A and B is still significantly corrosive. The hazard is increased by the fact that for the test to work the mixture temperature has to be raised to or near boiling. Strongly alkaline solutions are very prone to bumping when heated directly and this poses a serious risk, especially to the eyes. So as to lessen this risk, we have always recommended the use of a water bath to heat the reagent and the substance being tested.

The mechanism of Fehling's test relies on the fact that copper(II) is reduced to copper(I) by certain sugars in strongly alkaline solution. But in addition to alkali and a copper salt the recipe also includes tartrate ions which behave as a ligand, complexing the copper(II) ions and keeping them in solution. If these tartrate ions were not present, copper(II) ions then would be precipitated as copper(II) hydroxide, which readily decomposes into black copper(II) oxide. An unfortunate side effect is that tartrate also slowly reduces copper(II) to copper(I). This explains why, so as to lengthen the reagent's useful life, it is stored in two parts which are only mixed immediately before use.

Benedict's and Barfoed's Reagents both rely on sodium carbonate to provide the necessary alkaline conditions for the reduction of copper(II) to copper(I). They have long been recommended as alternatives to Fehling's. Both are 1M with respect to sodium carbonate, which is considerably less corrosive than Fehling's solution. A third reagent has now been reported on by Sandell in the Journal of Chemical Education [1].

This has been widely used in Sweden for more than 20 years. It contains EDTA as the complexing ligand, rather than tartrate ions, but more importantly it is only 0.5M with respect to sodium hydroxide. Since the solution remains alkaline and is used hot it would continue to be good practice to insist on the wearing of eye protection when carrying out the test. However, not only is this reagent less corrosive than Fehling's, but in our own trials we found a number of other advantages :

1. It can be stored as a single solution as the tartrate does not reduce the copper(II).
2. The colour change happens at temperatures as low as 60°C and direct heating with a flame is thus acceptable, if still strictly unnecessary.
3. Since the solution is a lighter blue than is Fehling's the brick red precipitate from a positive test is seen easier and earlier. With Fehling's the red precipitate of copper(II) oxide is so heavily masked by the dark blue, that pupils will often report a green precipitate.
4. It is easy and inexpensive to prepare.

It is fortuitous that whilst the EDTA ligand forms a more stable complex with the copper(II) than does the hydroxyl ion, thus preventing the precipitation of copper(II) hydroxide, it does not form a stable complex with copper(I). Thus the copper(I) oxide can be precipitated.

Recipe for Sandell's reagent

According to the published recipe, the reagent is prepared by dissolving 8.3 g of copper(II) sulphate-5-water and 18.6 g of EDTA, disodium salt-2-water in 800 cm^3 of deionised water and adding 200 cm^3 2.5M sodium hydroxide giving a final concentration with respect to sodium hydroxide of 0.5M. After a few days we found a slight white precipitate forming which settled firmly on the bottom of the bottle. The supernatant was decanted off and is still effective after two years.

Safety and convenience may be further enhanced if only slightly less sodium hydroxide is used than is called for in the original recipe. If, say, 200 cm^3 of 2M rather than 2.5M sodium hydroxide is used then the final solution will be 0.4M. It then may be classified and labelled as *IRRITANT* according to the CHIP Regulations instead of *CORROSIVE*. In fact we have found Sandell's reagent to detect, equally effectively, the presence of reducing sugars when made up with only half the sodium hydroxide concentration given in the original recipe. This provides a final concentration with respect to sodium hydroxide of only 0.25M. This less alkaline solution may well not work with other reducing agents. Also if the environment is acidic, for example after an acid hydrolysis of sucrose, it may need to be first neutralised with a little sodium hydroxide solution before proceeding to this test. With Fehling's we often forgot to take this experimental precaution and got away with it because of the large excess of alkali present in the reagent.

References

1 *A Handy Reagent for Testing the Reducing Power of Sugars*, Sandell A., Journal of Chemical Education, 71, 4, The American Chemical Society, April 1994.

2. *Archiv fur physiologische Heilkunde*, Fehling, H., 7, 1848.

Tiles : heating metals and oxides

In Bulletin 187 [1] we reviewed recent evidence that, in certain forms, some man-made fibres (MMF) may be carcinogenic. That article also assessed the risks of some specific educational uses of such fibres. Control measures, including; wherever possible, substitution were suggested. Ceramic fibres in varied forms are a type of MMF widely adopted as replacements for asbestiform minerals. One such replacement was the use of ceramic fibre-based paper tape in chemistry as an inert support for the heating of a range of materials such as metals and their oxides.

Ceramic paper tape is now hard to obtain. Conventional alternatives range from returning to the use of small borosilicate glass tubes - an expensive option - to the DIY recycling of crown bottle tops or similar container lids and tops. The latter is initially labour intensive since it involves removing any paper liners or seals and then pre-roasting the metal lids in an oven to remove paint and varnish. A third possibility - a low risk, low-cost substitute - is suggested here.

Ceramic wall tiles of the type sold for use in kitchens and bathrooms offer inexpensive alternatives to ceramic paper. The surface is usually easily cleaned for re-use. Size of tile is not critical; we used either 150 x 150 mm (nominal) types which were 6 mm thick, or 110 mm square tiles of 4 mm thickness. Cutting such tiles each into four strips produced pieces roughly 150 x 36 mm or 110 x 25 mm. In either case the resulting strips were long enough for one end to act as a handle and the other a heating surface. No tongs are needed.

The solid powders can be placed near one end of the strip of tile and the other end held by hand or the whole strip can be supported horizontally across one of the angles of the triangle of a tripod stand. The tile material is a sufficiently poor conductor of heat to allow it to be hand-held, but care is needed to grip it horizontally, or even with a small upward tilt away from you, else the bunsen flame may lick along the underside towards the hand.

These ceramic strips withstood several cycles of fierce heat and cooling. Tiles that had been deliberately soaked in water were quickly roasted without allowing time for drying out. No signs of cracking or crazing were observed.

The following operations also proceeded satisfactorily without damage to the tile:

- metals, including magnesium, zinc and iron, all in powder form, were heated and ignited;
- the oxides of copper(II) and lead(II) were reduced both with carbon powder and zinc powder;
- iron filings and sulphur powder in a 7:4 mix were reacted.

Strong heat from below allowed the reduction reactions to start. Equally they could be heated from above, initially with a gentle flame, in order to allow the powder to sinter. The carbon powder mixtures sometimes tended to "fluidise" when heated from below. They could then flow to the edge of the tile and fall off. For this reason the use of wider strips (ca. 36 mm) was eventually preferred.

One additional hazard is that the tile, unlike the ceramic paper of yore, has a high heat capacity and will be slow to cool down. Pupils will need to be trained to put tile strips down on heat resisting mats as they would with a crucible or test tube which had just been heated. Alternatively they could be rapidly cooled in water and then dried before reuse. It was generally easy to clean the tile afterwards, though some materials left a metallic smear.

The more enclosed nature of a test tube or of a crucible make both these vessels superior for reductions, but they have the disadvantage of higher price and of being potentially dangerous if unthinkingly used for some vigorously reacting mixtures.

As was the case with the formerly used ceramic paper, solid potassium manganate(VII) should not be heated on tile strips as small fragments of crystals are ejected violently during the decomposition of the compound. The advice was and still is to use a small amount in a tube filled with a loose plug of rocksil wool (previously roasted to oxidise away any organic impurities) or of glass wool (IRRITATING; handle with tongs [1]) .

The cut edges of tiles can be handled, but some schools may like to take the precaution of fitting a handle to cover up any sharp edges which might just remain. One way is to push fit pliable plastic tubing onto one end of the tile strip. Appropriate eye protection should of course be used for all the heating activities described as well as for the initial operation of cutting the strips of tile.

As indicated above it is usually possible to clean the used tiles afterwards. At about 8p for each 36 mm strip (£6 per pack of 18 budget tiles), then - when it proves impossible to clean them - they are best treated as disposable. Their cost compares well with that of either a porcelain crucible (£2.60) or a Pyrex or other borosilicate test tube (20p).

Reference

1. *Hazards of man-made mineral fibres*, Safety Notes, Bulletin 187, SSERC, Spring 1996.

Sheeps' eyes : dissection

We have had brought to our attention a copy of a letter circulated recently by the Department for Education and Employment (DfEE). Copies had been sent to all Chief Education Officers and other nominated DfEE contacts in England. This letter brought to the attention of such educational bodies the fact that, on 15th September of this year, the Ministry of Agriculture, Fisheries and Food (MAFF) had extended its controls on specified offal [1] to take in the heads of sheep and goats [2]. The letter then when on to retract the earlier advice that sheep (ovine) eyeballs could be substituted for bovine eyes in educational applications. Regular readers of the Bulletin may recall, from our earlier articles on this topic [3,4], that the Scottish Office Education and Industry Department (SOEID) has never advised the substitution of ovine for bovine eyes for such purposes. Nor has SSERC ever so advised. The new order affecting sheep and goat material thus makes no practical difference so far as educational activity in Scotland is concerned. As for other types of offal, not primarily of nervous origin, such as lungs, heart or liver, our earlier advice stands. We see no reason why such other materials - passed fit for human consumption and purchased on the Scottish retail market - should not continue to be used under controlled conditions for educational purposes.

Provided that good, hygienic, laboratory practice is followed; the educational benefit of such continued usage would seem to far outweigh the risks. Indeed much of positive benefit may be gained in showing pupils and students how such material may be handled and disposed of safely. If such activity should stimulate more informed and open discussion on the hazards and risks, modes of transmission etc. then so much the better for the pupils' science, and wider, education.

In the unlikely event that any schools are still holding stocks of preserved bovine or ovine eyes, and require advice as to their disposal, then we would be pleased to act as a first point of contact.

References

1. *The Bovine Offal (Prohibition) Regulations*, 1989 and amended 1995, S.I. 2061, HMSO, ISBN 0110980611.
2. *The Heads of Sheep and Goats Order*, 1996.
3. *Laboratory acquired infections*, Safety Notes, Bulletin 178, SSERC, September 1993.
4. *Bovine eyeball dissection*, Safety Notes, Bulletin 186, SSERC, Autumn 1995.

PUBLICATIONS OFFERS

CLEAPSS School Science Service

Laboratory Handbook

Recently we have been discussing with our colleagues in our sister organisation as to how the two organisations might co-operate yet more closely. One result has been a decision on our part to more actively promote some CLEAPSS publications for use in Scotland.

This provides near comprehensive coverage of matters technical and otherwise involved in the running of a school science department. It contains also much of use to those similarly engaged in FE. So wide is its coverage that *Handbook* is a misnomer. I'm sure that with hindsight a better title might have been *Vade-mecum.* Once the SVQ and NVQ for educational lab technicians come on stream, then this publication is sure to underpin major chunks of any training programmes.

In such an ambitious tome, there are bound to be minor omissions, as well as some matters of detail on which SSERC's approach might differ slightly. There are also occasional small irritations over the anglo-curricular language and references (that's not surprising either given the intended readership). None of this significantly detracts from its overall usefulness as a major work of reference for Scottish science teachers and technicians.

CLEAPSS have very kindly agreed to supply us with copies of the Handbook more or less at cost. That's the good news! The bad is that because of the sheer size of the publication - taken with the currently escalating costs of paper and thus print - means that the price of a single copy to SSERC clients is unlikely to be less than about £30 including postage and packing. The Handbook is such a useful and up-to-date reference work for science as a whole that £30 might well be shared out across the three separate sciences. Obviously the more orders we get the more we may be able to shave off that price.

SSERC 's: "Interfacing for . ."

A series for the three sciences

There has been a renewed demand for our courses on interfacing dataloggers and computers for practical activities and investigations. That has led Ian Birrell to begin updating our three volumes on interfacing for biologists, chemists and physicists. These publications have similar introductory sections each of which gives general background information and assumes little or no previous knowledge or experience. Advice on equipment is however tailored to the subject specialism. The introduction leads on to general techniques and thence to more subject specific material. Towards the end, some fairly advanced work is described. The availability of new types of hardware and software is taken into account. Stand-alone dataloggers as well as computer interfaces are covered.

The new edition for biology is available now and that for chemistry shouldn't be far behind. Because of any number of other priority tasks, the update for physics may not now be done until nearer our next appropriate course dates - after the turn of the year.

The packs are appropriate for use in independent learning, although their practical nature means that many teachers find a SSERC tutored course an easier way into such work. Nonetheless, these new editions should be of interest both to relative beginners and to those who have previously been on one of our courses and wish to update and practise their acquired skills. Each volume comes in a durable ring binder and costs £16 including post and packing. Orders can be accepted now for the biology and chemistry versions. Notes of interest will be welcomed and recorded for the physics volume. Enquiries and orders please, for any of the publications described on this page, to : The Director, SSERC, at the address given on the inside rear cover of this issue.

ODDS AND ENDS

Glycogen : grade and source

We have had enquiries lately on suitable types of glycogen - as an example of a carbohydrate - for use in food testing practicals. Not least of the considerations here are minimum quantity and price. For example, the smallest quantity sold by BDH McQuilkin is 25 g which would set you back almost £64.

Smaller amounts are available although you should not expect pro-rata prices. Small quantities necessarily attract something of a premium; but even a few grammes would last some time if only dilute suspensions are tested.

In our own shopping around, an everyday-kind-of-a, but potentially aphrodisiac, glycogen (extracted from oysters) seemed the most attractive. This is available from Sigma-Aldrich at £14 for 5 g. Next best was bovine liver glycogen from Fluka Chemicals at £6.60 for 1 g.

Plethysmography

Cry that syne ye hae a dram or twa! We've been asked what it means. Drawing lots of Greek letters?

A competition was tempting. It could have been worth it to see if anyone connected with Higher Still Biology, from whence it comes, could translate. I was asked by an SEB Biology Panellist, no less. That's not even the half of it. Cry it in full: *Venous Occlusion Plethysmography.* It's a method for measuring the blood flow into limbs. An arm, leg, or part thereof, is placed in a closed chamber connected by air, or other fluid, to a volume recorder (eg dashpot with lever or a manometer). An inflatable cuff is used to prevent outflow and total limb volume changes more or less in step with blood inflow. For a detailed explanation see texts on human physiology eg Green [1].

Reference

1. *An Introduction to Human Physiology*, J.H. Green, 4th Ed.1991 reprint, Oxford Medical Publications, OUP, ISBN 0-19-263328-7.

Surplus Equipment Offers

Items are arranged by similarity of application, or for other reasons, and not by stock number sequence. Often the item number serves only for stock identification by us in making up orders.

Newer stock items are underlined, so as to be more easily seen. Of particular interest is our limited stock of condenser lenses, which would ordinarily cost £80 each.

The prices quoted do not include VAT. However it is added to every customer's order. Local authority establishments will be able to reclaim this input VAT.

Postage and, where necessary, packing, will be charged for. It is therefore best not to send cash with an order, but wait for us to bill you. Official orders may be used. Please try and ask for at least £10 worth of goods because the administrative costs of handling orders are significant.

Don't send cash with orders

We repeat, please do not send payment with your order. Wait until you receive our advice note upon which payment may be made. This saves unnecessary complications e.g. when items are out of stock, failure to make provision for VAT, or if a delivery charge needs to be made. Items of equivalent value may be deducted from your order to balance any shortfall.

Motors

778 Stepper motor, Philips MB11, been stored in damp conditions but unused and retested. 4 phase, 12 V d.c., 100 mA per coil, 120 Ω coil per phase, step angle 7.5°, with 7 mm x 2 mm dia. output shaft. Dimensions 21 mm x 46 mm dia. on oval mounting plate with 2 fixing holes, diam. 3 mm, pitch 42 mm, at 56 mm centres. Circuit diagram supplied. £2.50

755 Pulley wheel kit comprising:
- plastic pulley wheel, 30 mm dia., with deep V-notch to fit 4 mm dia. shaft,
- two M4 grub screws to secure pulley wheel,
- Allen key for grub screws, and
- 3 mm to 4 mm axle adaptor.

The whole making up a kit devised for SSERC tachogenerators with 3 mm shafts. Specially supplied to SSERC by Unilab. £1.25

614 Miniature motor, 3 V to 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mN m, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 45p

593 Miniature motor, 1.5 V to 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mN m, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p

621 Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, eight tooth pinion on output shaft. 25p

739 Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia. 25p

732 Motor with gear box, high torque, 1.5 V to 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, or any other mechanism requiring a slow drive £6.00

773 Tachometer (ex equipment) £2.25

811 Worm and gear for use with miniature motors, 34 : 1 reduction ratio plastic worm and gear wheel. 35p

378 Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p

642 Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p

772 Encoder disk, 4-bit Gray code, stainless steel, 81.28 mm dia., 3 mm fixing hole, slots sized to register with components mounted on 0.1" stripboard. Applications: shaft position sensing, wind direction indicator. For related electronic circuitry see Bulletin 146. £3.00

Precision motor stock

785 Precision motor with optical shaft encoder, 0.25 to 24 V d.c., no load current and speed 9 mA and 6,600 r.p.m. at 24 V, stall torque 23 mNm, 9 segments. Overall body length including shaft encoder 59 mm, dia. 23 mm with output shaft 20 x 3 mm dia. Back EMF constant 3.6 V/1000 r.p.m. Suggested application - tachogenerator. Data on shaft encoder section available on application. £15

787 Precision motor with attached gearbox, 0.15 to 12 V d.c. With a supply of 3 V, the no load current is 25 mA and the output shaft turns at ca. 20 r.p.m. Gearbox ratio 1 : 365. Overall body length including gearbox 43.5 mm and diameter 16 mm. Output shaft 6 x 3 mm dia. with flat side to maximum depth of 0.3 mm along outer 5 mm length of shaft. Application - any system where a very slow angular velocity is required. £15

Miscellaneous items

791 Propeller, 3 blade, to fit 2 mm shaft, blade 55 mm long. 45p

792 Propeller kit with 10 hubs and 20 blades for making 2 or 3 bladed propellers. 130 mm diameter. Accepts either 2 mm or 3 mm shafts. £3.40

790 Buzzer, 3 V. 55p

827 Buzzer, 6 V. 55p

629 Dual tone buzzer with flashing light, mounted on small p.c.b. The unit has a PP3 battery clip and two flying leads for switch applications. 55p

cont./

710 Sonic switch and motor assembly. First sound starts the motor, a second reverses the direction of rotation, a third sound stops the motor. Driven by 4 AA cells (not supplied). 60p

715 Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 to 4 bar (i.e. above atmospheric). With rear fitting for $^1/_8$" BSP. Suitable for use as indicator for pneumatic circuits in Technological Studies. 75p

165 Bimetallic strip, length 10 cm;
high expansivity metal: Ni/Cr/Fe - 22/3/75
low expansivity metal: Ni/Fe - 36/64 (invar) 15p

166 Ditto, but 30 cm length. 40p

385 Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible). Dimensions 2" x 3" dia. 65p

419 Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V. 75p

753 Submersible pump, 6 V to 12 V d.c., 8 litres/min., 0.6 bar, dry operation protected. £5.50

758 Loudspeaker, 8 Ω, 0.5 W, 66 mm dia. 50p

771 Neodymium magnet, 13.5 mm dia. x 3.5 mm thick. £1.30

814 Ring magnet, 24 mm o.d., 6 mm i.d. 20p

815 Ceramic block magnets, random polarisation, 19 x 19 x 5 mm. 15p
823 Ceramic block magnets, poles at ends, 10 x 6 x 22 mm. 12p
824 Ceramic block magnets, poles on faces, 25 x 19 x 6 mm. 35p

825 Forehead temperature measuring strips, liquid-crystal type, 36-40°C (96-104°F). 50p

745 Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections. 40p

723 Microswitch, miniature, SPDT, lever operated. 40p

354 Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3. 10p

738 Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c. 75p

774 Solenoid, 12 V, stroke length 30 mm, spring not provided. £2.25

742 Key switch, 8 pole changeover. 40p

382 Wafer switch, rotary, 6 pole, 8 way. 70p

688 Croc clip, miniature, insulated, red. 5p

759 Ditto, black. 5p

788 Crocodile clip leads, assorted colours, insulated croc. clip at each end, 360 mm long. £1.35

809 Wire ended lamp, 3 V 10p

741 LES lamp, 6 V. 15p
770 ditto, but 12 V. 15p

789 MES lamp, 3.5 V, 0.3 A 9p
690 MES lamp, 6 V, 150 mA. 9p
691 MES battenholder. 20p

692 Battery holder, C-type cell, holds 4 cells, PP3 outlet. 20p

730 Battery holder, AA-type cell, holds 4 cells, PP3 outlet. 20p

729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730. 5p

724 Dual in line (DIL) sockets, 8 way. 5p

760 DIL sockets, 14 way. 7p

826 DIL sockets, 16 way. 8p

808 Electrodes for making lemon or other fruit cells etc. 1 pair, comprising 1 of copper, 1 of zinc, each approx. 60 mm square, per pair 50p

716 3-core cable with heat resisting silicone rubber insulation, 0.75 mm² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre. £1.35

756 Silicone coated, braided glass sleeving, yellow, 2.5 mm dia., gives both heat and electrical insulation to conductors (e.g. for autoclave rewiring). Price per metre. 55p

714 Sign "Radioactive substance" to BS spec., 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend. £2.70

763 Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm. £2.70

764 Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm. £2.70

727 Hose clamp, clamping diameter from 8 mm to 90 mm, 101 uses - securing hose to metal pipe, tree to stake, joining wooden battens for blueing, etc. 30p

731 Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack. 12p

752 Shandon chromatography solvent trough. £1.00

805 Condenser lens, bi-convex, 200 mm focal length, 75 mm dia. Crown glass. £12.50

806 Condenser lens, plano-convex, 150 mm focal length, 75 mm dia. Crown glass. £12.50

Components - resistors

329 Potentiometer, wire wound, 33 Ω, lin., 36 mm dia. 30p

420 resistors, 5% tolerance, ¼ W :
1R5, 4R7, 5R6, 6R8, 8R2, 10R, 15R, 22R, 33R, 47R, 56R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Per 10. 6p

421 DIL resistor networks, following values available: 62R. 1K0, 6K8, 10K, 20K, 150K. Per 10. 30p

BP100 Precision Helipots, Beckman, mainly 10 turn. 10p-50p

Components - capacitors

813 Capacitors, polystyrene: 4p
180 pF, 220 pF, 330 pF, 560 pF, 1000 pF, 2400 pF, 3000 pF, 3300 pF, 3900 pF & 4700 pF

695 Capacitors, tantalum, 15 μF 10 V, 47 μF 6.3 V. 1p

696 Capacitors, polycarbonate, 10 nF, 220 nF, 1 μF, 2.2 μF. 2p

697 Capacitor, polyester, 15 nF 63 V. 1p

698 Capacitors, electrolytic, 1 μF 25 V, 2.2 μF 63 V, 10 μF 35 V. 1p

358 Capacitor, electrolytic, 28 μF, 400 V. £1.00

Components - semiconductors

807 Schools' Chip Set, designed by Edinburgh University, comprises the 4 chips and prototype board. £4.00

Edinburgh University support material :
Volume 1 : Teaching Support Material (+£2 p&p). £4.50
Volume 2 : Laboratory Work (+£2 p&p). £5.00

322 Germanium diodes 8p

701 Transistor, BC184, NPN Si, low power. 4p

702 Transistor, BC214, PNP Si, low power. 4p

717 Triac, Z0105DT, 0.8 A, low power. 5p

725 MC74HC139N dual 2 to 4 line decoders/multiplexers 5p

699 MC14015BCP dual 4-stage shift register. 5p

711 Voltage regulator, 6.2 V, 100 mA, pre-cut leads. 10p

Sensors

615 Thermocouple wire, Type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); for making thermocouples, see Bulletins 158 and 165. £2.20

640 Disk thermistor, resistance of 15 kΩ at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162. 30p

641 Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162. £2.90

718 Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μm to >14 μm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 μm. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

751 Hacksaw blade with pair of strain gauges, terminal pads and leads attached. Suitable for impulse measurement as described in Bulletin 171. Delivery time 3 months. £12.50

501 Kynar film, screened, 28 μm thick, surface area 18 x 100 mm, coaxial lead and 4 mm connectors. Applications: Impulse (Bulletins 155 and 174), long wave infrared (Bulletin 155, SG Physics Technical Guide, Vol.2, pp 33-4) £20.00

503 Kynar film, unscreened, 28 μm thick, surface area 12 x 30 mm, no connecting leads. 55p

504 Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch. 10p

506 Resistor, 1 gigohm, ¼ W. £1.40

Opto-electronic devices

507 Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Priced per metre. 40p

508 LEDs, 3 mm, red. Price per 10. 50p
761 Ditto, yellow. Per 10. 60p
762 Ditto, green. Per 10. 60p

Items not for posting

All of the following items are only available to callers because of our difficulties in packing and posting glassware and chemicals. We will of course hold items for a reasonable period of time to enable you to arrange an uplift.

Glassware

664 Flat bottom round flask, 500 ml. 50p

768 Sodium lamp, low pressure, 35 W. Notes on method of control available on application. 85p

810 Watch glasses, assorted sizes 20p

Chemicals etc.

712 Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc. large, 50p, small 35p

NB : Other chemicals are named here as described on supplier's labels. Please order according to our description. Unless coded "A" substances are not Analar grade. Must be collected.

ammonia sol'n, 27% w:w 2.5 l :	50p
barium sulphate (soil tests), 500 g	50p
calcium sulphate (for soil testing), 500 g	25p
decanoic-n-acid (lauric), 500 ml	25p
iron (III) nitrate(V)-9-H_2O, A, 250 g	50p
Keiselguhr acid, washed, 500 g	25p
lead oxide, (red lead - Pb_3O_4)500 g	25p
methanol, 2 l	50p
nickel (ii)sulphate(VI)-7-H_2O, A, 250 g	50p
resorcinol, 100 g	10 p
sodium n-butyrate, 100 g	25p
tetrachloroethylene, 2.5 l	50p
zinc (II) ethanoate-2-H_2O, 250 g	50p
zinc ethanoate-2-H_2O, A, 250 g	60p

Ex-evaluation equipment

Because of changes in agency arrangements we are in position to offer for sale a number of items of high quality physics equipment manufactured by *Pasco Scientific*. These we had originally obtained for evaluation. All are in nearly-new condition although some have had a degree of usage on our interfacing courses for physics. The prices shown offer substantial savings. They are net of VAT and carriage will be charged at cost. These items are offered on a first-come, first-served basis.

828 Accessory : photogate (Pasco ME9204A), 65 mm wide, fully adjustable swivel mount, LED trigger indicator, Easily adaptable to suit other manufacturers' timing units. £43.50

829 Free fall adaptor, (Pasco ME9207A). A spring loaded release system for dropping a steel ball, which automatically starts an electronic timer. The timer stops when the ball lands on a receptor pad. Timer not included. £69.30

830 Digital photogate timer with memory, (Pasco ME9215A). Modes : gate, pulse, pendulum, manual stopwatch. Resolution 0.1 ms, maximum time interval 1.999 s. Accuracy ± 1%. 4.5 digit LCD display, 9 mm high. Accepts ME9204A photogates or TTL compatible signals. Power : 4 C cells or 9 V d.c. adaptor. £158.90

831 Fan cart, (Pasco ME9485), Features : rotatable fan for measuring component forces; two speed motor; ultra-low friction wheels mounted on common axles for straighter running. £42.70

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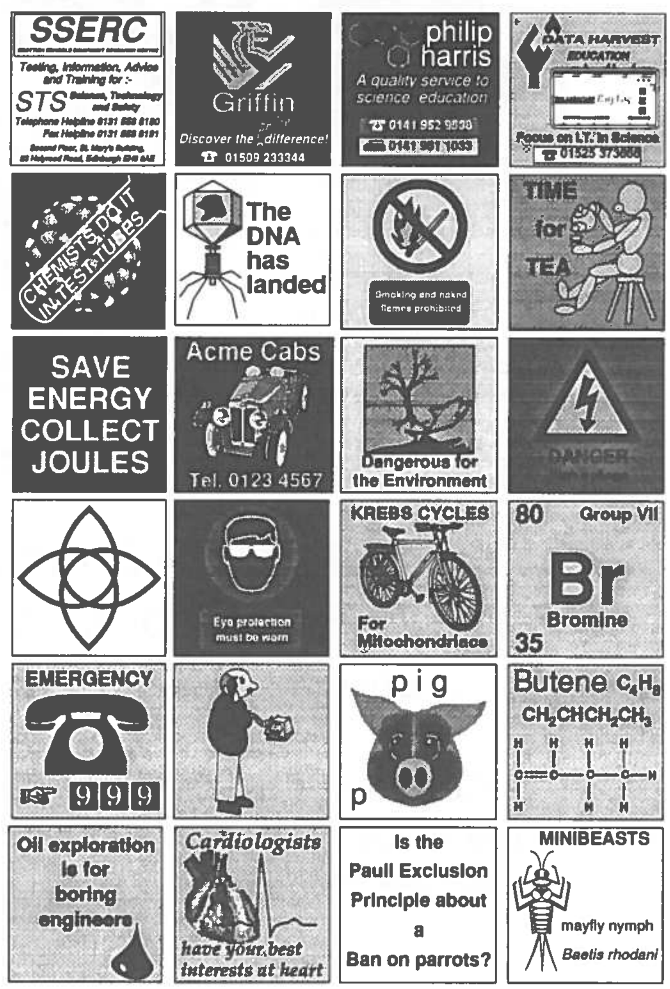

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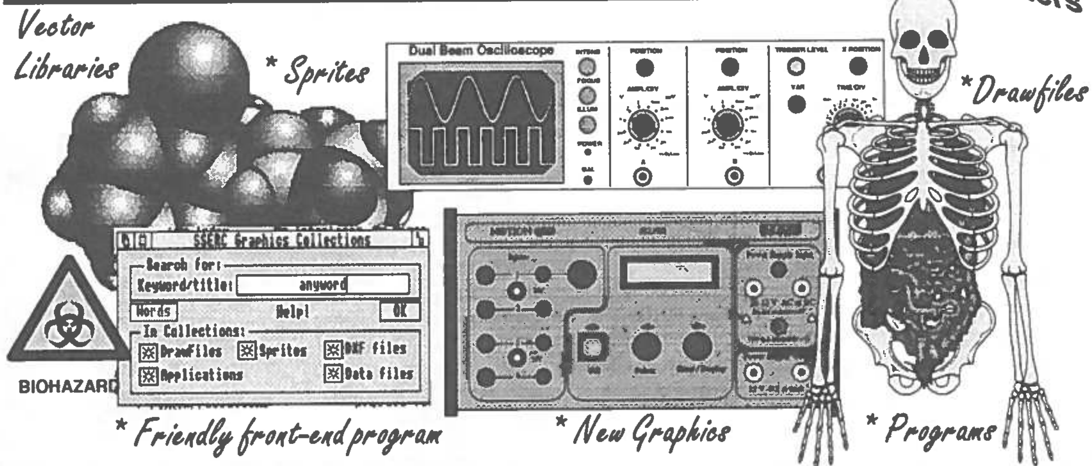

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Macks Mill Cottage, Gordon, Berwickshire, TD3 6JY; Tel./Fax 01573 410537.

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